**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

| | |
|---|---|
| In re the Application of: | |
| **Pacetti et al.** | **Group Art Unit:** 1762 |
| **Serial No.:** 10/040,538 | **Examiner:** Erma Cameron |
| **Filed:** December 28, 2001 | |
| **For:** A SYSTEM AND METHOD FOR COATING IMPLANTABLE DEVICES | |

Mail Stop Appeal Brief-Patents
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

## APPEAL BRIEF

Dear Sir:

On April 4, 2007, Applicant appealed to the Board of Patent Appeals from the final rejection of Claims 1-6, 9-11, 13, 15-26, 33-36, 41, 44-46, 48-60 and 71-78. The following is Applicant's Appeal Brief submitted pursuant to 37 C.F.R. §41.37.

## REAL PARTY IN INTEREST

The real party in interest is Advanced Cardiovascular Systems Inc., a California corporation, having a place of business at 3200 Lakeside Drive, Santa Clara, California 95054. The original assignment to Advanced Cardiovascular Systems Inc. was recorded at Reel/Frame 013074/0885 on April 26, 2002. Effective February 13, 2007, Advanced Cardiovascular Systems Inc. changed its name to Abbott Cardiovascular Systems Inc.

## RELATED APPEALS AND INTERFERENCES

There are no related appeals or interferences related to or that might have any bearing, direct or indirect, on the Board's decision in this appeal.

## STATUS OF CLAIMS

Claims 1-7, 9-26 and 33-78 are pending in the application.

Claims 8 and 27-32 are cancelled.

Claims 7, 12, 14, 37-40, 42, 43, 47 and 61-70 are withdrawn.

Claims 1-6, 9-11, 13, 15-26, 33-36, 41, 44-46, 48-60 and 71-78 are finally rejected and form the subject of this appeal.

## STATUS OF AMENDMENTS

There are no unentered amendments.

## SUMMARY OF CLAIMED SUBJECT MATTER

The pending claims include 5 independent claims: claims 1, 23, 54, 61 and 73.

Independent claim 1 is directed to a method of coating an implantable medical device. The method involves applying a composition, from a coating dispenser, including a solvent to an implantable medical device and directing a gas, from a gas dispenser positioned at a distance from the coating dispenser, onto the implantable medical device, wherein if the solvent has a vapor pressure greater than 17.54 Torr at ambient temperature the temperature of the gas is adjusted to decrease the evaporation rate of the solvent, and if the solvent has a vapor pressure of less than 17.54 Torr at ambient temperature the temperature of the gas is adjusted to increase the evaporation rate of the solvent. (*See* specification at page 3, line 17 to page 4, line 2)

Independent claim 23 is directed to a method of coating an implantable medical device. The method involves applying a composition, from a coating dispenser, including a solvent to an implantable medical device and blowing a gas, from a gas blower positioned at a distance from the coating dispenser, directly onto the implantable medical device to either increase or decrease the evaporation rate of the solvent from the composition on the implantable medical device,

wherein if the solvent is non-volatile the temperature of the gas is adjusted to increase the evaporation rate of the solvent, and if the solvent is volatile the temperature of the gas is adjusted to decrease the evaporation rate of the solvent. (*See* specification at page 4, lines 8-15)

Independent claim 54 is directed to a method of coating a stent. The method involves positioning a stent on a support assembly, applying a coating substance including a solvent from a dispenser to the stent, blowing a gas from a blower onto the stent to either increase or decrease the evaporation rate of the solvent from the coating substance on the stent based on the volatile properties of the solvent and rotating the stent supported by the support assembly about a longitudinal axis of the stent. (*See* specification at page 6, line 15 to page 10 line 5)

Independent claim 61 is directed to a method of coating a stent. The method involves positioning a stent on a support assembly, rotating the stent about the longitudinal axis of the stent positioned on the support assembly, applying a coating substance including a solvent from a dispenser to the stent, blowing an inert gas from a blower onto the stent to either increase or decrease the evaporation rate of the solvent based on the volatility of the solvent and optionally repeating applying and blowing wherein the stent is rotated about the longitudinal axis of the stent on the support assembly during the applying of the coating substance and the blowing of the gas. (*See* specification at page 6, line 15 to page 10 line 5)

Independent claim 73 is directed to a method of coating a stent. The method involves applying a composition, from a coating dispenser, including a solvent to a stent and blowing an inert gas, from an inert gas blower positioned at a distance from the coating dispenser, directly onto the stent to increase the rate of evaporation of the solvent from the composition on the stent. (*See* specification at page 6, line 15 to page 10 line 5)

## GROUNDS OF REJECTION TO BE REVIEWED ON APPEAL

Whether claims 1-6, 11, 13, 17-19, 21-24, 33-36, 44, 46, 48-54, 57-60, 71 and 72 are anticipated by, and therefore unpatentable under 35 U.S.C. § 102(e) over U.S. Pat. No. 6,395,326 to Castro et al. (Castro) (Evidence Appendix A).

Whether claims 9, 10, 15, 16, 20, 25, 26, 41, 45, 55, 56 and 73-78 are obvious, and therefore unpatentable under 35 U.S.C. § 103(a) over Castro.

Whether claims 1-6, 9-11, 13, 15-26, 33-36, 41, 44-46, 48, 49, 51-58, 60 and 71-78 are obvious, and therefore unpatentable under 35 U.S.C. § 103(a) over U.S. Pat. No. 6,358,556 to Ding et al. (Ding) in view of U.S. Pat. No. 6,407,009 to You et al. (You) (Evidence Appendices B and C).

## ARGUMENT

Claims 1-6, 11, 13, 17-19, 21-24, 33-36, 44, 46, 48-54, 57-60, 71 and 72 are not anticipated by, and therefore patentable under 35 U.S.C. § 102(e) over U.S. Pat. No. 6,395,326 to Castro

The Examiner has rejected claims 1-6, 11, 13, 17-19, 21-24, 33-36, 44, 46, 48-54, 57-60, 71 and 72 under 35 U.S.C. § 102(e) as anticipated by Castro in the Final Office Action dated January 5, 2007. (*See* Appendix D). The Examiner has simply maintained the rejection of the claims over Castro from the previous Office Action dated April 19, 2006. (*See* Appendix E) Additionally, the Examiner has added that "Castro teaches air pressure to deliver the coating, including burst of air."

Castro was also cited in the Office Actions dated September 30, 2004 and July 5, 2005 as anticipatory over the present invention. (*See* Appendices F and G)

Applicants respectfully submit that the Examiner is misreading the claims of the present invention, has an unreasonably broad reading of Castro, including reading elements into the reference, and has ignored well established case law.

Applicants' Response

For the following reasons, the rejection of the claims 1-6, 11, 13, 17-19, 21-24, 33-36, 44, 46, 48-54, 57-60, 71 and 72 over Castro is improper:

(1) In the Final Office Action dated January 5, 2007, the Examiner has contended in support of the rejection that "Castro teaches air pressure to deliver the coating, including bursts of air pressure." Applicants respectfully fail to see the relevancy of this position as the claims are clearly demarcated between a coating dispenser and a gas dispenser positioned at a distance from the coating dispenser. It appears, as the Applicants are merely resorting to conjecture based on lack of an adequate explanation in the office action, that the Examiner may be equating the coating dispenser of Castro as being both a coating dispenser as well as a gas dispenser. The

Examiner's reasoning would follow that Castro teaches application of a gas as claimed. This reasoning is misplaced, however, since the claims are directed to a gas dispenser being positioned at a distance from a coating dispenser. If the coating and gas dispenser are one and the same, then one cannot be placed at a distance from the other.

(2) As correctly indicated by the Examiner, Castro does teach a heating element for curing or drying of a coating substance. As indicated in col. 11, lines 11-16, "a heating assembly is used for controlled drying and/or curing of a coating on prosthesis 12. As shown in FIG. 5A, heating assembly 52 can be a device including a heating conduit 45, a heating nozzle 56 having an orifice 58 through which heat is delivered and a heating control system 60."

Castro, however, fails to teach that the heating assembly does or is capable of directing a gas as claimed. There is absolutely no teaching in Castro that a heated or cooled gas is applied to the stent via the nozzle. Application of heat in Castro can be by many means, such as a heated coil or a conductive pin positioned in the opening of the nozzle (charged pin that can glow and generate heat). Using gas cannot be read into the teaching of Castro since Castro has no indication of its use.

Additionally, with respect to independent claims 23, 54 and 73 there is absolutely no teaching in Castro of "blowing ... gas, from a ... blower" onto an implantable medical device. The use of heated or cooled gas blown onto an implantable medical device is not disclosed by Castro.

(3) Applicants and the Examiner have certainly hit an impasse as to whether Castro teaches directing or blowing of a gas. Applicants believe that the Examiner is adding this limitation into the four corners of Castro. The Examiner differs in her opinion. However, regardless of this issue, with respect to claim 1, Castro fails to at least teach "if the solvent has a vapor pressure greater than 17.54 Torr at ambient temperature the temperature of the gas is adjusted to decrease the evaporation rate of the solvent, and if the solvent has a vapor pressure of less than 17.54 Torr at ambient temperature the temperature of the gas is adjusted to increase the evaporation rate of the solvent". Castro teaches absolutely no condition of temperature adjustment based on the vapor pressure 17.54 Torr of the solvent. Applicants agree that dimethyacetamide is disclosed in Castro, including a variety of other solvents that are also disclosed by the current invention. However, the mere disclosure of a solvent having a low

vapor pressure does not amount to teaching of a method of adjusting gas temperature based on the volatility of the solvent used. Similarly, with respect to claims 23 and 54, Castro fails to teach a method wherein the temperature of the gas is dependent on the volatility of the solvent.

(4) In the Office Action dated July 5, 2005, the Examiner responded to Applicants' argument that Castro fails to teach directing or blowing of gas by reasoning that Castro has to teach blowing of gas based on the hardware components disclosed by Castro. In other words, the Examiner reasoned that because Castro teaches a conduit, nozzle and opening, there is no other plausible use for such components but for blowing of gas.

Applicants would like to echo the same arguments presented in the response filed -- namely, there are other plausible explanations other than the one to which the Examiner has latched. The conduit of Castro can be used for running wires to the control system such as a motion control system as disclosed by Castro; the nozzle can be used for housing a heating coil or glowing pin and to prevent direct contact of the substrate to the heating element; and the opening can be used to project the direction of the heat.

Furthermore, Castro teaches capability of "discretely" heating very small areas of struts, such as cavities. (Col. 11) A flow of gas is much harder to regulate or localize than heat emitted from a heating pin. Col. 18, lines 52-59 requires the heat to follow the preselected geometrical pattern of the composition which on the stent struts would be less than 1 mm. Air blowing is more attune with systemic heating not localized heating.

(5) In the July 5, 2005 Office Action, the Examiner attempted to justify her position with respect to Castro by stating that "[s]ince Castro does not teach conveying and projecting of a warm liquid (as such would wet, not dry the coating), it is immediately clear to an ordinary artisan that Castro is conveying and projecting gas." (emphasis original)

The Examiner has taken the position that since the reference does not teach A, it must teach B, even though B is not taught by the reference. In other words, the Examiner tried to establish the existence of B, even though B is lacking, by arguing the lack of existence of A. Applicants respectfully submit that this reasoning in support of an anticipatory rejection is grossly improper. There is no legal precedent that says a claimed element can be illustrated by a reference, even though its not disclosed in that reference, based on the lack of existence of another element. The law on anticipation is very simple, in that the reference either teaches the

element or does not teach the element. In the case at bar, Castro simply fails to teach the elements of the claims.

(6) In support of the Castro rejection, in the protracted file history, the Examiner has also reasoned that "one of ordinary skill in the art, upon reading Castro, would immediately envision the use of heated gas." (Office Action dated April 19, 2006).

The test for anticipation is not whether "one of ordinary skill in the art would envision the missing claimed element". A claimed element is either present or is not present. If it is not present, the anticipation rejection fails unless the claimed element is inherently present. With respect to the doctrine of inherency, the courts have made it very clear that inherency cannot be based on a possibility or probability but must be necessarily present. *In re Robertson*, 169 F.3d 743, 745, 49 USPQ2d 1949, 1950-51 (Fed. Cir. 1999). The Applicants have provided other very logical possibilities with respect to the heating element of Castro -- namely, a glow pin or a heating coil. The Examiner has in essence rejected the holding of *In re Robertson*, and has stated that inherency cannot be avoided if other possibilities are shown so long as the Examiner decides that one of the possibilities is more reasonable than the other, as evident by the Office Action of April 19, 2006, page 5. The Examiner has rejected the ruling of *In re Robinson* based on the fact that the Examiner found her version of the possibility more plausible than the Applicants' version of the many other possibilities. Applicants respectfully submit that the basis for the rejection was and is presently flawed as the Federal Circuit has not provided a standard that if other possibilities exist, an examiner must chose what he or she thinks is the more reasonable possibility.

(7) Finally, in a response dated October 13, 2006 to the April 19, 2006 Office Action, Applicants submitted declarations from Daniel Castro, Syed Hossainy and Li Chen. (Evidence Appendices H, I and J) As one of ordinary skilled in the art and as inventors of the Castro patent itself, each declared that Castro, their own invention, does not teach what is claimed in the independent claims of the present invention. Applicants respectfully submit that these declarations should be sufficient to remove the Examiner's conjured and fallacious version of Castro's teachings.

On page 5 of the Office Action dated January 5, 2007, the Examiner opines that that declaration is insufficient to overcome the rejection because "the declarations offer no

substantive reasons for their statement that [Castro] does not teach each of the independent claims, and are merely an opinion."

Applicants respectfully believe that the Examiner's statement is flawed in two ways: First, declarations based on opinions are perfectly acceptable and have traditionally been sufficient to overcome rejections, such as obviousness-type rejections. For example, a declaration by an expert stating that in his or her opinion the invention is not obvious has been given credence towards patentability.

Second, Applicants fail to see why any substantive opinion need be given when the Applicants have produced statements from the inventors of the reference being cited against them. The declarations are not from anyone skilled in the art but the inventors of the Castro reference itself. In other words, the inventors of Castro are declaring that their patent does not teach that which the Examiner is arguing it teaches. Applicants do not understand why any reason needs to be given when the inventors of the reference claim that they did not conceive that which the Examiner is arguing they have conceived.

For the above reasons, reversal of the rejection is respectfully requested.

Claims 9, 10, 15-16, 20, 25, 26, 41, 45, 55, 56 and 73-78 are unobvious, and therefore patentable under 35 U.S.C. § 103(a) over Castro

The Examiner has rejected claims 9, 10, 15, 16, 20, 25-26, 41, 45, 55, 56 and 73-78 under 35 U.S.C. § 103(a) as obvious over Castro. As indicated above, independent claims 1, 23, 54 and 73 are patentably allowable over Castro. Therefore, claims 9-10, 15-16, 20, 25-26, 41, 45, 55, 56 and 74-78 dependent thereon, are also allowable over Castro.

The Court has rejected a rigid application of the "teaching, suggestion or motivation" (TSM) test which required a showing of some teaching, suggestion or motivation in the prior art that would lead one of ordinary skill in the art to combine the prior art elements in the manner claimed in the application for a finding of obviousness. The Court instructs that while the TSM test can be a factor in determining unobviousness, secondary factors, e.g., long felt need, commercial success, unexpected results, etc., are also to be given weight. KSR International Co. v. Teleflex Inc. et al., 550 U.S. (2007).

Secondary factors, however, are not germane to finding unobviousness in the present case since Castro does not teach or suggest all of the claim limitations.

Moreover, the Examiner has consistently failed to provide any adequate reasoning as to why each dependent claim is deemed anticipated or obvious over Castro. Even if Castro did teach blowing of gas, it certainly fails to teach:

(1) simultaneous application as recited by claims 3, 44, and 52;

(2) any overlapping gas flow ranges or ranges that are remotely near what has been claimed by claim 15;

(3) partial stent expansion during both applying the composition and blowing of the gas by claim 19;

(4) the use of an inert gas by claims 20, 45 and 56;

(5) the temperature of the gas being significantly less than the boiling temperature of the solvent by claim 24;

(6) gas temperature as disclosed by claim 25;

(7) change in temperature of the coating composition by claim 26;

(8) simultaneous application of coating composition and gas wherein the gas does not affect the spray direction of the coating composition by claim 33;

(9) the gas comprises nitrogen by claims 74 and 78;

(10) the gas is argon by claim 75; and

(11) the gas temperature is 40 deg. C to 90 deg. C by claim 77.

These limitations are not disclosed by Castro and have been consistently brushed over in the examination of the application – which is well short of what is required by the Examiner. For example, the Examiner has failed to indicate why the use of nitrogen and argon, as compared to other gases would be obvious. With respect to claim 15, Castro fails to provide any gas flow range, let alone overlapping ranges or ranges in close proximity that could under the rules be deemed *prima facie* obvious. With respect to claim 77, the Examiner has indicated that 40 deg. C "is only slightly above room temperature." Applicants respectfully submit, in the field of chemical arts and processing arts, a difference of 15 deg. C should not be trivialized as "only slightly."

Therefore, reversal of the rejection is respectfully requested.

Claims 1-6, 9-11, 13, 15-26, 33-36, 41, 44-46, 48, 49, 51-58, 60 and 71-78 are unobvious, and therefore patentable under 35 U.S.C. § 103(a) over Ding in view of You

The Examiner has rejected claims 1-6, 9-11, 13, 15-26, 33-36, 41, 44-46, 48, 49, 51-58, 60 and 71-78 under 35 U.S.C. § 103(a) as obvious over Ding in view of You. The Examiner has simply maintained the rejection of the claims over Ding in view of You from the previous Office Action dated April 19, 2006. Ding and You were also cited in the Office Actions dated September 30, 2004 and July 5, 2005 for making obvious the present invention.

Applicants' response

(1) The Examiner has indicated than Ding does in fact teach directing a gas onto a stent. The Examiner opines that Ding teaches an air brush for coating deposition, and therefore the Applicants are assuming that the Examiner believes that the air of the coating brush is equivalent to the gas dispenser of the claims. Again, as with Castro, Applicants respectfully submit that the Examiner is not reading the claims correctly. Claims 1, 23, and 73 require a gas dispenser or blower that is positioned at a distance from the coating dispenser. If the coating dispenser and gas blower are one and the same, they cannot be positioned at a distance from one another.

(2) With respect to independent claim 1, the references alone or in combination fail to teach each and every element of the claim. Neither Ding nor You teach that the temperature of the gas is based on a solvent vapor pressure greater than 17.54 Torr at ambient temperature, as recited in claim 1. For this reason alone, claim 1 is patentably allowable over Ding in view of You.

(3) With respect to independent claims 1, 23, and 73 the references alone or in combination fail to teach "directing the gas onto an implantable medical device" or blowing the gas "directly onto the implantable medical device." Ding simply fails to teach the use of any kind of gas blower for blowing gas. Applicants assume that the Examiner is relying on You to fulfill this deficiency. However, You falls short of this teaching. You teaches that "the chamber space 103 can be cooled adiabatically by using the bias gas stored under pressure and released into the chamber at a pressure lower than the storage pressure of the gas" (col. 5 lines 66 and 67

continuing to col. 6, lines 1 and 2). Releasing gas into a chamber to cool the chamber holding a semiconductor substrate is not equivalent to blowing a gas directly onto an implantable medical device. In one instance, cold gas is introduced in an environment in which a substrate is placed and in the other instance a gas is blown directly onto the substrate. To make an analogy, if on a warm day a person is sitting in an air conditioned room, the air conditioning may be blowing in the room but not directly onto the person. The person will feel the coolness of the room but not the blowing of the air conditioning. The person has to stand right in front of the air conditioning and at a distance close enough that the air is directly being applied to the person or in other words, the person is feeling the cool air blowing on her face. One is not the same as the other. For at least this reason, claims 1, 23, and 73 are patentably allowable over the combination of the references.

(4) Applicants submit that a *prima facie* case of obviousness has not been established. There is absolutely no motivation in the references to make the combination. Ding does not mention anything with respect to coating defects as well as drug migration to upper regions of the coating or out from the stent. Ding does not mention the adverse effect that solvent systems could possibly have on a drug. Applicants therefore submit that if Ding is silent on all these issues, why would one in the stent art refer to the semiconductor reference of You to correct any coating problems that Ding may have? Moreover, if You is directed at preventing cracking of residual deposited material as well as increasing the dielectric and mechanical strength of the material leading to longer lifetimes for semiconductor devices, why would a combination of You and Ding make sense, considering the materials used for coating stents are different than semiconductor coating materials?

Indeed, the issues surrounding coating a semiconductor wafer are not equivalent to coating of stents. One is directed at coating a flat, two dimensional, solid structure. The other is directed at coating a three-dimensional tubular structure with a hollow opening. One is directed at coating a large (for example 8 inches in diameter), flat surface area. The other is directed at coating struts less than 1 mm in width and gaps or openings between the struts. One is directed at a being open to all forms of manufacturing processes, while the other is limited to standards that have to be approved by the FDA, including material used.

Applicants can appreciate how easy it is for a key word search to be completed finding two disparate references that teach a combination of what has been claimed and working

backwards to try to justify why the reference can be combined since both are in the field of coating technology. But the fact of the matter is that many companies, including giants such as Johnson and Johnson, Boston Scientific, and Medtronic have been working on releasing a drug delivery stent into the market for years, some as far back as 10 years, and so far only two, Johnson and Johnson and Boston Scientific have a product in the US market. This being said, Boston Scientific has had a product recall based on manufacturing problems that they encountered. This is well documented news. So by trying to trivialize this invention by trying to justify the applicability of a semiconductor reference to the invention at hand is quite misplaced.

Additionally, with respect to motivation, not from the reference, but in knowledge generally available to one of ordinary skill in the art, applicants submit the following: (1) this technology is a brand new technology which lacks general availability and know how; and (2) considering that even the Examiner made an error in describing the reasoning of the motivation to combine -- namely, prevention of "cracking," (Office Action dated September 30, 2004, page 7 – see discussion in paragraph (5) below) Applicants submit that this error in and of itself is *prima facie* evidence of non-obviousness.

(5) In order to rely on a reference as a basis for rejection of an applicant's invention, the reference must either be in the field of applicant's endeavor or, if not, then be reasonably pertinent to the particular problem with which the invention was concerned. *In re Oetiker*, 977 F.2d 1443, 1446, 24 USPQ2d 1443, 1445 (Fed. Cir. 1992).

Applicants agree that Ding is in the field of Applicant's invention. You, however, relates to deposition of semiconductor thin films. Therefore, Applicants believe that You is not within the field of Applicant's endeavor of coating medical devices. Should the Board consider You in Applicants' field of endeavor, then Applicants respectfully submit that the first branch of the Oetiker test becomes meaningless. In essence the Board would be holding that any thing whatsoever that has to do with coating would fall within the scope of the present invention, including painting of a wall. The holding of *In re Oetiker* becomes grossly undervalued or understated if such a broad interpretation were to be followed. Coating medical devices is vastly more sophisticated than painting of a wall, and one skilled in the art of painting walls is certainly not qualified to coat medical devices for drug delivery. Similarly, coating a flat wafer if vastly different than coating an intricately small three-dimensional surface of a stent.

With respect to the second branch of the test, namely, if it is not in the same field of endeavor, then the reference must be reasonably pertinent to the particular problem with which the invention was concerned, the Examiner is on record as stating that the teaching of the references is reasonably pertinent to the particular problem of preventing the coating from "cracking" (pages 6 and 7 of the Office Action dated September 30, 2004).

This is not actually the case. The fact that the Examiner is incorrect, on the record, about the combination of references being pertinent to the problem of preventing cracking should be sufficient to hold that the obviousness rejection is without merit.

Problems with stent coating cracking have to do with the brittleness and glass transition temperature of the polymer and the stress applied to the coating by the stent during crimping and/or expansion of the stent. As described by the specification of the present invention, the problems which the invention at bar are addressing includes "cob-web" formation between stent struts, drug retention, minimization of interaction of the drug to the solvent (which could adversely affect the drug) and enabling the stent to hold enough drug for the effective treatment of the patient.

As indicated by the specification, initial portions of the liquid composition containing a drug are deposited on the stent. However, it is believed that as liquid composition continues to be applied to the stent, layers of composition form on top of one another. It is further believed that the drug, when exposed to solvents in the upper layer, can re-dissolve into the upper layer or be extracted out from the coating. Having the drug maintained in merely the upper region of the coating provides for a short residence time of the drug at the treatment site or burst release of the drug out from the coating. There is nothing in the reference that is even remotely pertinent to the particular problems with which this invention is concerned.

In Stratoflex, Inc. v Aeroquip Corp., 713 F.2d 1530, 218 USPQ 871 (Fed. Cir. 1983), the court stated that the problem confronting the inventor was preventing electrostatic buildup in PTFE tubing caused by hydrocarbon fuel flow while precluding leakage of fuel. Two prior art references relied upon were in the rubber hose art, both referencing the problem of electrostatic buildup caused by fuel flow. The court found that because PTFE and rubber are used by the same hose manufacturers and experience the same and similar problems, a solution found for a problem experienced with either PTFE or rubber hosing would be looked to when facing a problem with the other.

The facts at bar are severely in contrast to what has been presented by Stratoflex. The Ding reference has no mention of stent coating problems. The You reference is directed at preventing cracking of residual deposited material as well as increasing the dielectric and mechanical strength of the material leading to longer lifetimes for semiconductor devices. Neither of the references discusses problems addressed by the present invention. Drug eluting stents, which have been incredibly challenging to coat based in intricate geometries, need severe FDA scrutiny, and have been in development for over 10 years with only two companies having a product in the US market (Boston Scientific and Johnson and Johnson). Drug eluting stents do not share the same manufacturing issues as a large and flat surface of a semiconductor wafer. Moreover, one skilled in the art of dealing with the issue of preventing a drug from migrating to upper layers of a stent coating does not look at a reference for increasing the dielectric strength of a semiconductor device to make adjustment to the manufacturing process.

(6) The Examiner has provided no objective reasoning to make the combination as required by Ex parte Levengood, 28 USPQ1300 (Bd. Pat. App. & Inter. 1993). Applicants agree that these two references can be combined – anything can be combined; but the law is very clear, that the mere fact that the references can be combined does not render the resultant combination obvious unless there is suggestion to make the combination. The only reason why this combination was made is because the Examiner has used the hindsight of the Applicants' claim to make the combination – otherwise such a far fetched semiconductor reference would not have been used.

As correctly indicated by the Examiner in the Office Action dated April 19, 2006, Ding "enables a thin layer of coating material to adherently conform to and cover the entire surface of the filaments of the open structure of the stent but in a manner such that the open lattice nature of the structure of the braided or other pattern is preserved in the coated device." (emphasis provided by the Examiner) The Examiner was referring to col. 3, lines 53-58 of Ding which states "[t]he coating process enables the material to adherently conform to and cover the entire surface of the filaments of the open structure of the stent but in manner such that the open lattice nature of the structure of the braid or other pattern is preserved in the coated device."

Simply put, Ding teaches that they have "enabled" a method that results in coating conformity while preventing any coating substance to cover the gaps between the stent filaments. In other words, this language teaches that the method enabled by Ding provides for a coating that

does not suffer from non-coating conformity drawbacks. Yet, according to the Examiner, one reading Ding would be motivated to look at a semiconductor reference, which is outside the field of the Applicants' endeavor, to correct coating conformity in Ding even though Ding has enabled a method that does not need any correction of the coating conformity. Applicants respectfully submit that this logic is counterintuitive as one of ordinary skill in the art reading Ding would not be motivated to resort to a semiconductor reference -- a reference which is far from the field of the medical device endeavor -- to cure a problem that Ding specifically states does not exist. In sum, one of ordinary skill in the art would not be motivated to fix coating conformity where the reference teaches that it has enabled a method that results in excellent coating conformity.

(7) In the Final Office Action dated January 5, 2007, the Examiner, in response to the Arguments made in paragraph (6) above, opined that the "motivation to combine is to add the controlled drying aspect of the You invention to the Ding process, not to 'correct' conformity of the Ding coating." (emphasis added) So the Examiner has changed the motivation to make the combination yet again, for the third time.

The Examiner has been so incredibly inconsistent about the reasoning as to why the combination should be made that such "flip flopping" in and of itself should be profoundly in support of why motivation to combine does not exist. In the Office Action dated September 30, 2004, on page 7, the Examiner noted that "it would have been obvious to incorporate the teaching of You et al. into the process of Ding et al. ... in order to ensure that the deposited coating does not crack...." In the response that followed, the Applicants pointed out to the Examiner that coating cracking is technically without merit and not at issue. Next, in the Office Action dated July 5, 2005, the Examiner modified the motivation to combine, noting on page 10 that motivation is based on achieving a conformal, uniform coating. Applicants responded to this rational by the arguments reiterated in paragraph (6) above. In sum, the Applicants challenged the Examiner to provide a reason why one skilled in the art would want to modify the method of Ding to produce a conformal coating when Ding teaches that it has enabled a uniform conformal coating.

Instead of responding to the Applicants inquiry, in the Final Office Action of January 5, 2007, the Examiner conceded that correction of coating conformity was not a reason for making the combination. The Examiner crafted yet a third reason why the combination should be made, namely to "control" the drying aspect of Ding. To summarize, the motivation has been changed

from preventing coating cracking, to producing coating conformity, to controlling the drying aspect of Ding. The motivation for combining Ding with You appears to be a moving target, changing with each office action. Applicants should not be obligated to chase a moving target, and from the prosecution of this application, it is quite evident that a sound rebuttal to this third reasoning will have no affect but to produce a fourth grounds for motivation to combine.

In the latest round, the Examiner is suggesting that one skilled in the art would be motivated to add an extra method step to the process of Ding to control drying even though (1) Ding is absolutely silent about needing a more controlled drying step; and (2) Ding explicitly teaching that they do not suffer from any coating problems which may require an additional processing step.

More particularly, Ding specifically teaches an oven curing step in which the "pre-polymer and crosslinking agents cooperate to produce a cured polymeric matrix." (Col. 8, lines 28-31) Ding specifically states that the solvent is evaporated during the oven curing step. (Col. 8, lines 31 and 32) If the Examiner is suggesting substituting the blowing of gas step with the curing step of Ding, then the blowing of gas might not cure the pre-polymer using the crosslinking agent as prolonged exposure with high temperature are typically necessary for curing of the Ding polymers (see Ding Col. 8, lines 36-40, requiring 90 deg. C or higher for 16 hours). Moreover, there is no motivation provided for substituting the gas blowing step for the oven curing step. If the Examiner is suggesting adding an additional step of gas blowing, either before or after the curing step, this additional step adds an extra manufacturing step which prolongs the stent coating process. Additionally, one skilled in the art would not be motivated to change the coating process of Ding since, according to Ding, their coating process works perfectly fine with excellent coating properties.

Furthermore, application of air across a surface of the stent presents many challenges and its use might not be considered to be "controlled" by one skilled in the art, as is argued by the Examiner. Gas flow can vary from one part of the stent to another part. This may result in the solvent evaporating at a faster rate at one area of the stent as compared to another area of the stent. In turn, this may translate into unwanted drug migrating to the upper surface of the stent leading to drug release variation across the body of the stent. The Examiner has failed to provide an iota of reasoning as to why application of gas leads to a more "controlled" drying step as compared to Ding's application of heat in a controlled oven environment. In summary, application of gas is far from controlled as trivialized by the Examiner.

(8) Applicants respectfully submit that the references clearly teach away from each other. It is improper to combine references where the reference teaches away from their combination." *In re Grasselli*, 713 F.2d. 731, 743, 218 USPQQ 769, 779 (Fed. Cir. 1983).

As indicated by the Examiner on page 7 of the Office Action dated April 19, 2006, the object of Ding is to preserve the open lattice structure from the coating material. In other words, Ding teaches that the gaps of the substrate must not be filled with a coating substance. In contrast, You teaches that it is an "object of the invention" to manufacture "spin-on layers with better gap filling properties." (col. 3, lines 1 and 2) You specifically requires the gaps of the substrate to be filled. This is accomplished by inhibiting the evaporation of the solvent such that the viscous precursor material fills the gaps of the You substrate. The evaporation of the solvent can be accomplished by adiabatically cooling the chamber, application of a cooled biased gas, and cooling of the wafer.

In sum, Ding teaches a method of preventing the gaps of the substrate from being filled while You is specifically directed to the modification of its coating parameters to reduce the evaporation rate of the solvent such that the gaps in the substrate are filled. This is a classic case of two references teaching away from one another.

In response to the argument that the references teach away from each other, in the Final Office Action dated January 5, 2007, on page 5, the Examiner countered that "the fact that Ding has open lattice work and You does not is immaterial to the combination." The Examiner reasoned that "only certain aspects of the You process ... are being added to the Ding process." (emphasis added)

The Examiner has made both a legal error and a factual error. With respect to the legal error, the standard is very clear in that "a prior art reference must be considered in its entirety, i.e., as a whole, including portions that would lead away from the claimed invention (MPEP 2141.03). Yet, the Examiner is on the record stating that she is doing exactly that which the patent office has proclaimed Examiners should not do.

With respect to the factual error, the Examiner has incorrectly characterized the references. The reason that You does not include an open lattice network is because it is a semiconductor wafer and not an implantable medical device. Regardless, both devices do include gaps. Ding includes gaps between the stent struts and You includes gaps in the wafer. Ding teaches that its gaps between the strut should not be filled and You teaches that its gaps

should be filled. Therefore portions of the reference that teach away from the combination are material to an obviousness rejection. The Examiner is grossly in error to opine that such teachings are "immaterial to the combination."

Applicants have provided 8 solid reasons why the rejection is without merit. Reversal of the rejection is respectfully requested.

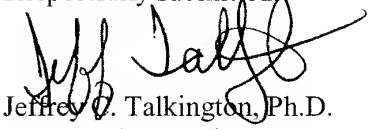
With respect to the dependent claims, the combination of Ding and You suffer from the same problems discussed above with respect to Castro. In other words, not only have the Applicants received an inadequate examination of the dependent claims, the Examiner has simply ignored Applicants' responses. For example, in the response of October 13, 2006, Applicants provided that the combination fails to teach the elements of claim 3 – simultaneous application of coating and gas to the stent. In fact You teaches that the precursor for the wafer is applied before the application of the gas. The Examiner appears to have completely ignored this point. Applicants also provided in the response that the combination fails to teach adjusting the temperature of the coating composition prior to application to the device based on the solvent volatility. Again, this issue was overlooked by the Examiner. Regardless, the dependent claims are allowable by virtue of their dependency and reversal of the rejection is respectfully requested.

## CONCLUSION

The Examiner has failed, as a matter of law, to set forth a case of anticipation under 35 U.S.C. § 102(e) over Castro or *prima facie* obviousness under 35 U.S.C. § 103(a) over Castro and Ding in view of You. Appellants therefore respectfully request that the Board reverse these rejections and order the application to proceed to issue.

Date: July 3, 2007

Respectfully submitted,



Squire, Sanders & Dempsey L.L.P.
One Maritime Plaza, Suite 300
San Francisco, CA 94111-3492
(415) 954-0200

Jeffrey C. Talkington, Ph.D.
Attorney for Applicants
Reg. No. 44,826

# CLAIMS APPENDIX

## CLAIMS APPENDIX

The claims on appeal are:

1. A method of coating an implantable medical device comprising:

applying a composition, from a coating dispenser, including a solvent to an implantable medical device; and

directing a gas, from a gas dispenser positioned at a distance from the coating dispenser, onto the implantable medical device, wherein if the solvent has a vapor pressure greater than 17.54 Torr at ambient temperature the temperature of the gas is adjusted to decrease the evaporation rate of the solvent, and if the solvent has a vapor pressure of less than 17.54 Torr at ambient temperature the temperature of the gas is adjusted to increase the evaporation rate of the solvent.

2. The method of Claim 1, wherein the implantable medical device is a radially expandable stent.

3. The method of Claim 1, wherein the composition is applied simultaneous with the directing of the gas.

4. The method of Claim 1, wherein the composition includes a polymer dissolved in the solvent and optionally an active agent added thereto.

5. The method of Claim 4, wherein the polymer is ethylene vinyl alcohol copolymer and the solvent includes dimethylacetamide.

6. The method of Claim 1, wherein the composition comprises paclitaxel, docetaxel, or rapamycin or analogs or derivative thereof.

7. The method of Claim 1, wherein the act of applying the composition is terminated prior to the act of directing the gas.

9. The method of Claim 1, wherein the act of applying comprises using a nozzle of the coating dispenser to spray the composition onto the implantable medical device, wherein the distance from the tip of the nozzle to the outer surface of the implantable medical device is from about 0.5 cm to about 5.0 cm.

10. The method of Claim 1, wherein the applying is conducted by atomized spaying of the composition at a flow rate of about 0.01 mg/second to about 1.0 mg/second.

11. The method of Claim 1, wherein the act of applying comprises spraying the composition onto the implantable medical device.

12. The method of Claim 11, wherein the gas is blown directly onto the implantable medical device and the direction of the flow of the gas is substantially in the same direction as the composition spray.

13. The method of Claim 11, wherein the gas is blown directly onto the implantable medical device and the direction of the flow of the gas is at an angle relative to the direction of the composition spray.

14. The method of Claim 11, wherein the gas is blown directly onto the implantable medical device and the direction of the flow of gas is substantially opposite to the direction of the composition spray.

15. The method of Claim 1, wherein the act of directing the gas is performed at a flow rate of about 300 feet/minute to about 10,000 feet/minute.

16. The method of Claim 1, wherein the gas is blown directly onto the implantable medical device.

17. The method of Claim 1, wherein the implantable medical device is a stent and the method further comprises rotating the stent about a central longitudinal axis of the stent.

18. The method of Claim 1, wherein the implantable medical device is a stent and the method further comprises moving the stent in a linear direction along the longitudinal axis of the stent.

19. The method of Claim 1, wherein the implantable device is a stent and the stent is at least partially expanded during the acts of applying and directing.

20. The method of Claim 1, wherein the gas comprises an inert gas.

21. The method of Claim 1, wherein the gas is selected from a group of argon, nitrogen and air.

22. The method of Claim 1, further comprising changing the temperature of the implantable medical device to a temperature other than ambient temperature.

23. A method of coating an implantable medical device comprising:

applying a composition, from a coating dispenser, including a solvent to an implantable medical device; and

blowing a gas, from a gas blower positioned at a distance from the coating dispenser, directly onto the implantable medical device to either increase or decrease the evaporation rate of the solvent from the composition on the implantable medical device, wherein if the solvent is non-volatile the temperature of the gas is adjusted to increase the evaporation of the solvent, and if the solvent is volatile the temperature of the gas is adjusted to decrease the evaporation rate of the solvent.

24. The method of Claim 23, wherein if the solvent is volatile, the temperature of the gas is significantly less than the boiling temperature of the solvent.

25. The method of Claim 23, wherein the temperature of the gas is about 25°C to about 200°C for the non-volatile solvent and is less than 25°C for the volatile solvent.

26. The method of Claim 23, further comprising, if the solvent is non-volatile increasing the temperature of the composition to a temperature above ambient temperature prior to application

of the composition onto the implantable device, or alternatively, if the solvent is volatile decreasing the temperature of the composition to a temperature below ambient temperature prior to application of the composition onto the implantable device.

33. The method of Claim 1, wherein applying the composition comprises spraying of the composition; wherein the directing of the gas comprises blowing the gas directly onto the device; wherein the spraying and blowing are conducted simultaneously; and wherein the blowing does not affect the direction of the spray onto the device.

34. The method of Claim 1 wherein the implantable medical device is a stent and wherein the stent is rotated during the application of the composition or directing of the gas.

35. The method of Claim 1, wherein the coating and/or gas dispenser is controlled by a central processing unit.

36. The method of Claim 1, wherein a controller controls the temperature and/or flow speed of the gas from the dispenser.

37. The method of Claim 1, wherein application of the composition is terminated prior to directing of the gas and where the method additionally comprises repeating the steps until a desired amount or thickness of coating is deposited.

38. The method of Claim 1, wherein the application of the composition is terminated prior to directing of the gas and wherein the gas is blown directly onto the stent after a waiting period.

39. The method of Claim 1, wherein the steps of applying and directing are performed in sequence a multiple number of times and wherein the method additionally comprises a time period between each step.

40. The method of Claim 1, wherein the application of the composition is terminated prior to directing of the gas and wherein the gas is blown directly onto the implantable medical device for 1 second to 100 seconds.

41. The method of Claim 1, wherein the implantable medical device is a stent and wherein the stent is rotated during the coating process at a speed of 0.1 rpm or higher.

42. The method of Claim 23, wherein the applying the composition is terminated prior to blowing the gas directly onto the implantable medical device.

43. The method of Claim 23, wherein the steps of applying and blowing are conducted in sequence and, optionally, repeated a number of times.

44. The method of 23, wherein the steps of applying and blowing are conducted simultaneously.

45. The method of Claim 23, wherein the gas comprises an inert gas.

46. The method of Claim 23, wherein the gas comprises air.

47. The method of Claim 23, wherein the implantable medical device is a stent; wherein the applying of the composition is terminated prior to blowing of the gas; and wherein the method additionally comprises rotating the stent about the longitudinal axis of the stent during the act of applying and/or blowing.

48. The method of Claim 23, wherein the composition includes a polymer.

49. The method of Claim 23, wherein the composition includes a drug.

50. The method of Claim 23, wherein the composition includes paclitaxel, docetaxel, or rapamycin or analogs or derivative thereof.

51. The method of Claim 23, wherein the implantable medical device is a stent; wherein the stent is supported by a support assembly; and wherein the method additionally comprises rotating the stent about a longitudinal axis of the stent.

52. The method of Claim 23, wherein the implantable medical device is a stent, wherein the stent is supported by a support assembly; wherein the steps of applying and blowing are conducted simultaneously; and wherein during the steps of applying and blowing the stent is rotated about a longitudinal axis of the stent on the support assembly.

53. The method of Claim 23, wherein applying is via spraying.

54. A method of coating a stent comprising;

positioning a stent on a support assembly;

applying a coating substance including a solvent from a dispenser to the stent;

blowing a gas from a blower onto the stent to either increase or decrease the evaporation rate of the solvent from the coating substance on the stent based on the volatile properties of the solvent; and

rotating the stent supported by the support assembly about a longitudinal axis of the stent.

55. The method of Claim 54, wherein the stent is rotated at 0.1 rpm or higher.

56. The method of Claim 54, wherein the gas comprises an inert gas.

57. The method of Claim 54, wherein the gas comprises air.

58. The method of Claim 54, wherein the coating substance includes a drug.

59. The method of Claim 54, wherein the coating substance includes paclitaxel, docetaxel, or rapamycin or analogs or derivative thereof.

60. The method of Claim 54, wherein the coating substance includes a polymer dissolved in the solvent.

61. A method of coating a stent comprising:

positioning a stent on a support assembly;

rotating the stent about the longitudinal axis of the stent positioned on the support assembly;

applying a coating substance including a solvent from a dispenser to the stent;

blowing an inert gas from a blower onto the stent to either increase or decrease the evaporation rate of the solvent based on the volatility of the solvent; and

optionally repeating applying and blowing wherein the stent is rotated about the longitudinal axis of the stent on the support assembly during the applying of the coating substance and the blowing of the gas.

62. The method of Claim 61, wherein the stent is rotated at 0.1 rpm or higher.

63. The method of Claim 61, wherein the gas comprises nitrogen.

64. The method of Claim 61, wherein the gas consists of nitrogen.

65. The method of Claim 61, wherein the coating substance includes a drug.

66. The method of Claim 61, wherein the coating substance includes paclitaxel, docetaxel, or rapamycin or analogs or derivative thereof.

67. The method of Claim 61, wherein the coating substance includes a polymer dissolved in the solvent.

68. The method of Claim 61, additionally comprising adjusting the temperature of the gas.

69. The method of Claim 61, wherein the step of applying comprises spraying.

70. The method of claim 69, additionally comprising waiting for a period of time between the applying followed by the blowing and/or waiting for a period of time between the blowing followed by the applying.

71. The method of Claim 1, wherein the opening of the gas dispenser is pointed at and facing the implantable medical device.

72. The method of Claim 23, wherein the opening of the gas dispenser is pointed at and facing the implantable medical device.

73. A method of coating a stent comprising:

applying a composition, from a coating dispenser, including a solvent to a stent; and

blowing an inert gas, from an inert gas blower positioned at a distance from the coating dispenser, directly onto the stent to increase the rate of evaporation of the solvent from the composition on the stent.

74. The method of Claim 73, wherein the gas is nitrogen.

75. The method of Claim 73, wherein the gas is argon.

76. The method of Claim 73, wherein the temperature of the gas is 25°C to 200°C.

77. The method of Claim 73, wherein the temperature of the gas is 40°C to 90°C.

78. The method of Claim 23, wherein the gas comprises nitrogen.

## EVIDENCE APPENDIX

Attached hereto are the following:

(A) U.S. Pat. No. 6,395,326 to Castro et al. - Cited by the Examiner in the Final Office Action dated January 5, 2007.

(B) U.S. Pat. No. 6,358,556 to Ding et al. - Cited by the Examiner in the Final Office Action dated January 5, 2007.

(C) U.S. Pat. No. 6,407,009 to You - Cited by the Examiner in the Final Office Action dated January 5, 2007.

(D) Final Office Action dated January 5, 2007.

(E) Office Action dated April 19, 2006.

(F) Office Action dated September 30, 20004.

(G) Office Action dated July 5, 2005.

(H) Declaration under 37 C.F.R § 1.132 of Daniel Castro – Entered by the Examiner in the Final Office Action dated January 5, 2007.

(I) Declaration under 37 C.F.R § 1.132 of Syed Hossainy - Entered by the Examiner in the Final Office Action dated January 5, 2007.

(J) Declaration under 37 C.F.R § 1.132 of Li Chen - Entered by the Examiner in the Final Office Action dated January 5, 2007.

EVIDENCE APPENDIX "A"

US006395326B1

(12) **United States Patent**
**Castro et al.**

(10) **Patent No.: US 6,395,326 B1**
(45) **Date of Patent: May 28, 2002**

(54) **APPARATUS AND METHOD FOR DEPOSITING A COATING ONTO A SURFACE OF A PROSTHESIS**

(75) Inventors: **Daniel Castro**; **Steven Wu**, both of Santa Clara; **Kevin L. Woolbright**; **Kurt W. Scheinpflug**, both of Sunnyvale; **Syed F. A. Hossainy**, Fremont; **Li Chen**, San Jose, all of CA (US)

(73) Assignee: **Advanced Cardiovascular Systems, Inc.**, Santa Clara, CA (US)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/583,371**

(22) Filed: **May 31, 2000**

(51) **Int. Cl.**[7] ..... **A61L 27/00**; A61L 29/00; A61L 31/00; A61L 33/00

(52) **U.S. Cl.** ..... **427/2.24**; 427/2.25; 427/2.28; 427/2.3; 427/261; 427/286; 427/287

(58) **Field of Search** ..... 427/2.24, 2.25, 427/2.28, 2.3, 261, 286, 287, 256, 258, 8

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 5,464,650 | A * | 11/1995 | Berg et al. | 427/2.3 |
| 5,837,313 | A * | 11/1998 | Ding et al. | 427/2.21 |
| 5,873,904 | A * | 2/1999 | Ragheb et al. | 623/1 |
| 6,096,070 | A * | 8/2000 | Ragheb et al. | 623/1 |
| 6,121,027 | A * | 9/2000 | Clapper et al. | 435/180 |
| 6,209,621 | B1 * | 4/2001 | Treacy | 164/516 |
| 6,214,407 | B1 * | 4/2001 | Laube et al. | 427/2.24 |

FOREIGN PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| WO | WO-98/23228 | * 6/1998 | | A61F/2/06 |

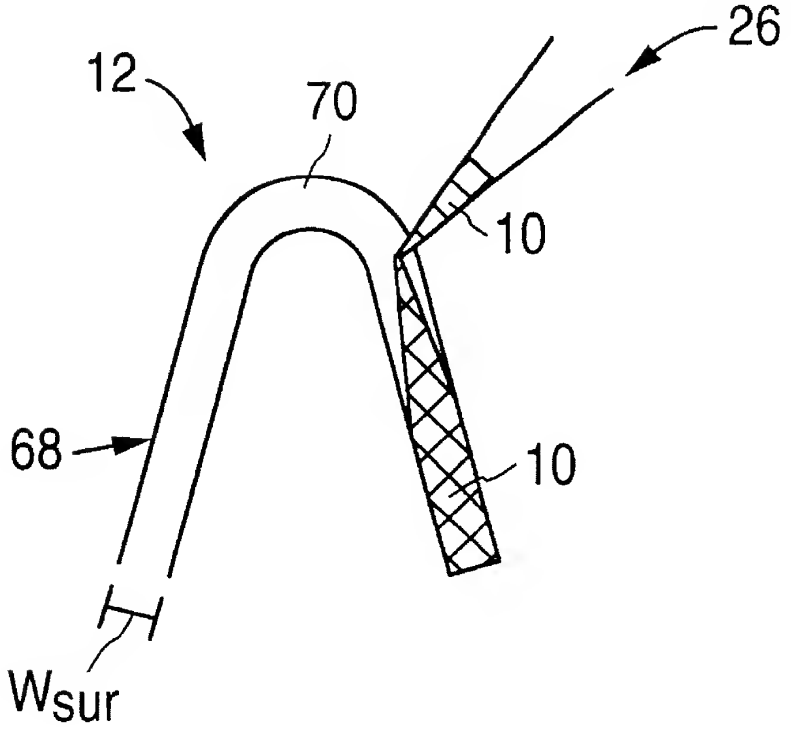
* cited by examiner

*Primary Examiner*—Shrive P. Beck
*Assistant Examiner*—Jennifer Kolb Michener
(74) *Attorney, Agent, or Firm*—Squire, Sanders & Dempsey LLP

(57) **ABSTRACT**

A patterned coating on a prosthesis, for example a stent, and a method for forming the coating are disclosed. Additionally, an apparatus for forming the patterned coating is disclosed.

**25 Claims, 14 Drawing Sheets**



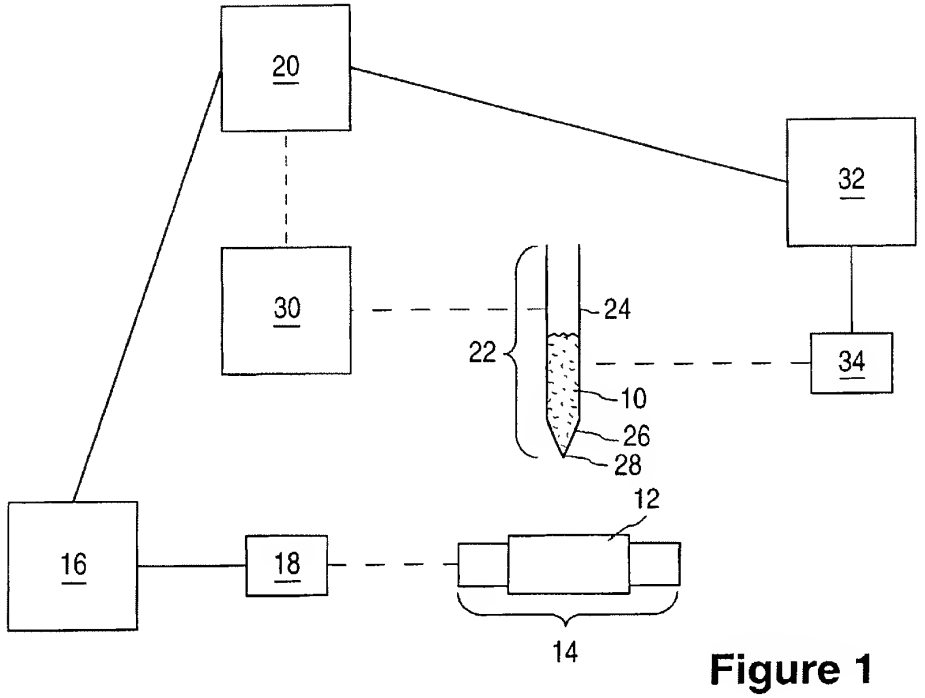



Figure 1

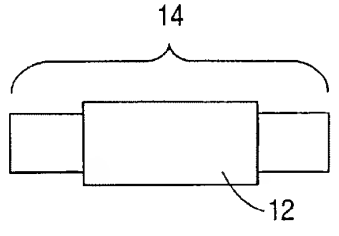



Figure 2A

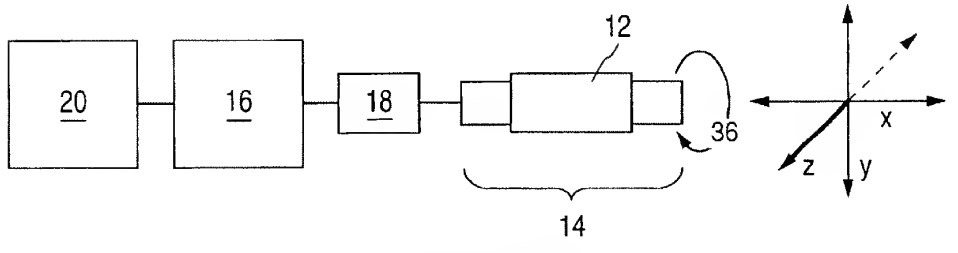



Figure 2B

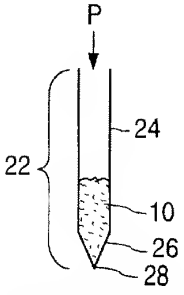



Figure 3A

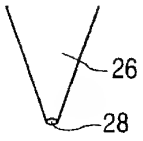



Figure 3B

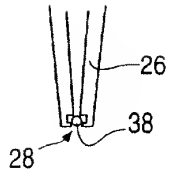



Figure 3C

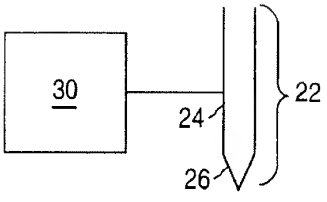



Figure 3D

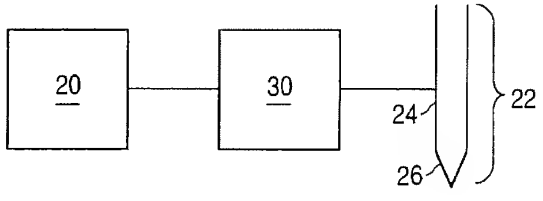



Figure 3E

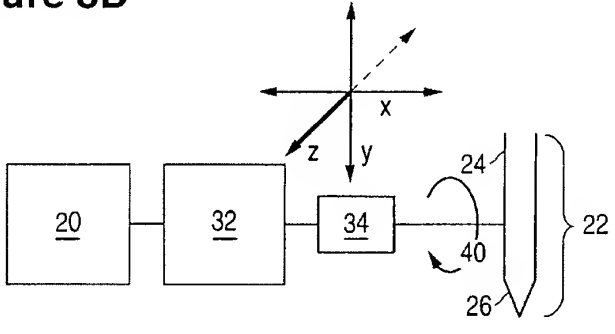



Figure 3F

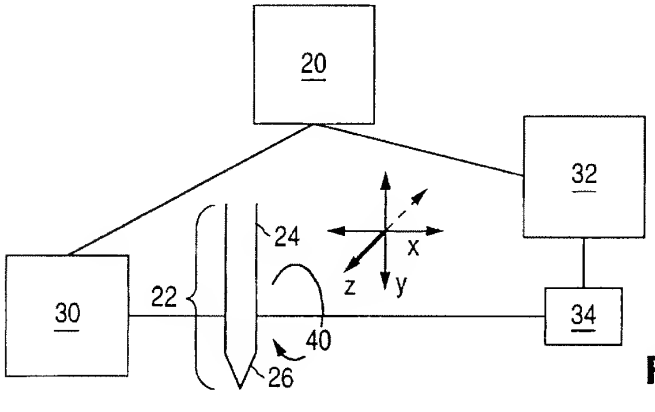



Figure 3G

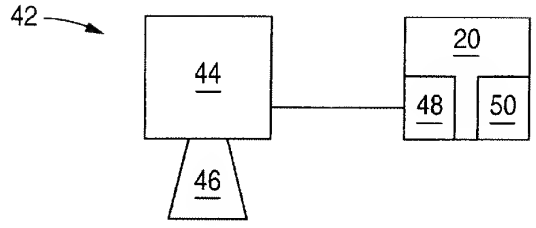



Figure 4A

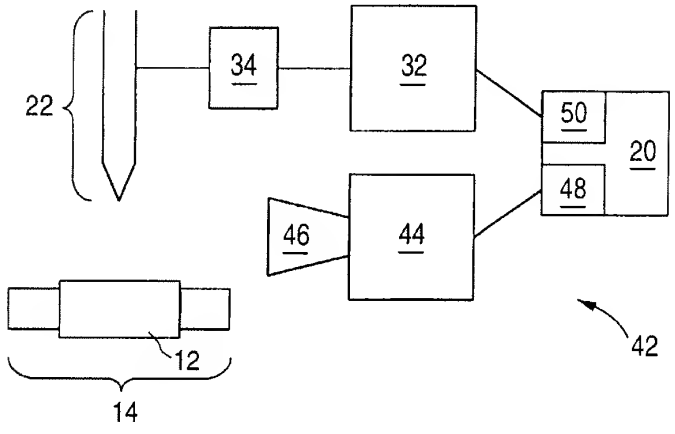



Figure 4B

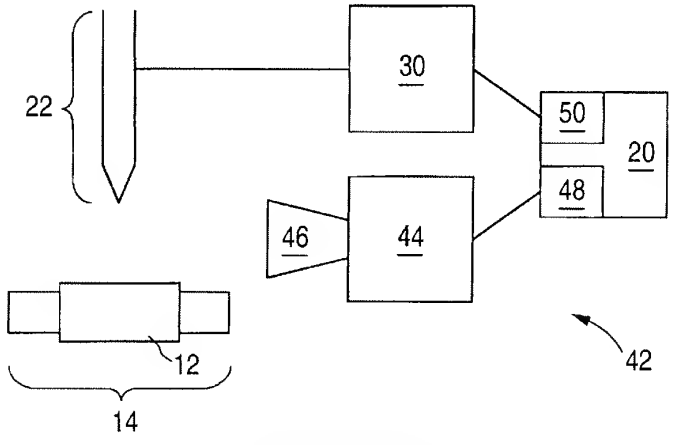



Figure 4C

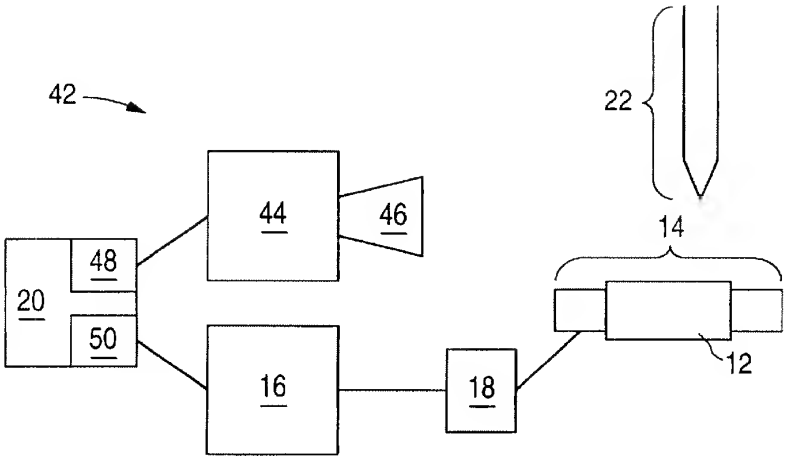



Figure 4D

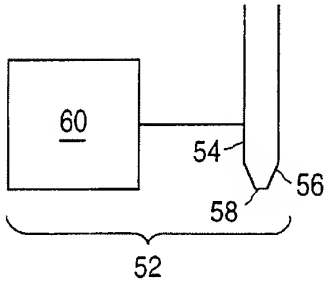



Figure 5A

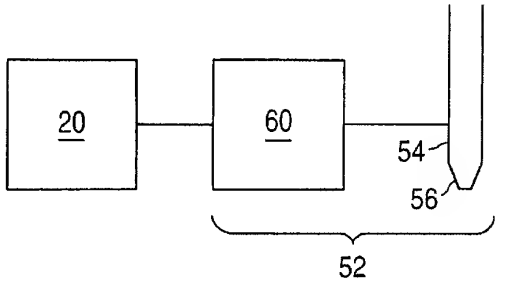



Figure 5B

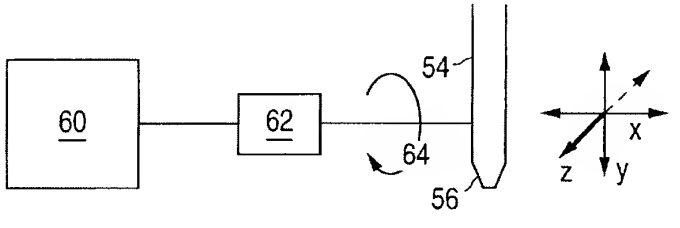



Figure 5C

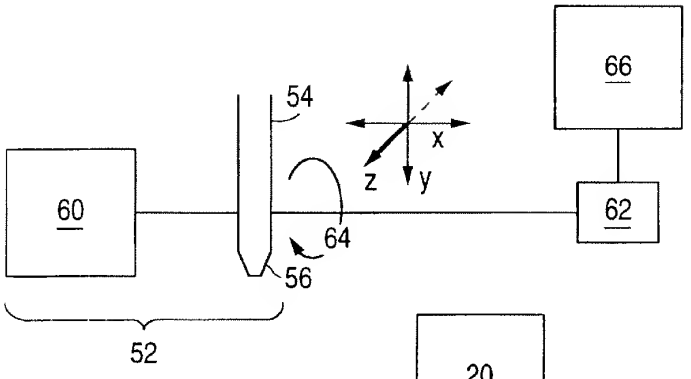



Figure 5D

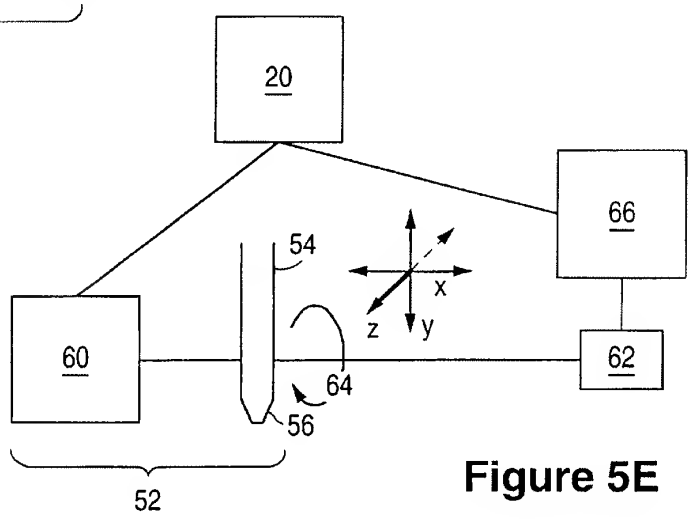



Figure 5E

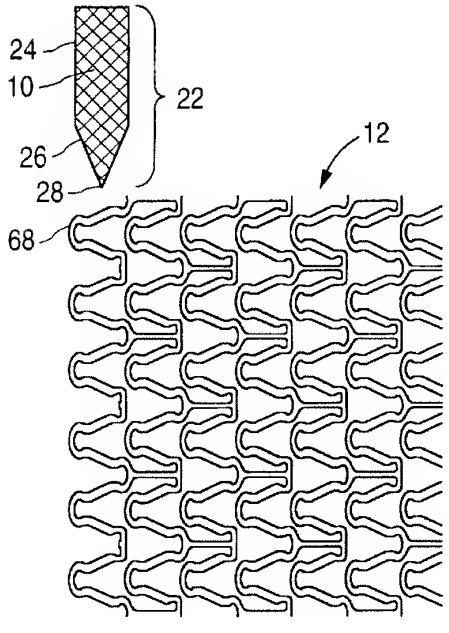



Figure 6A

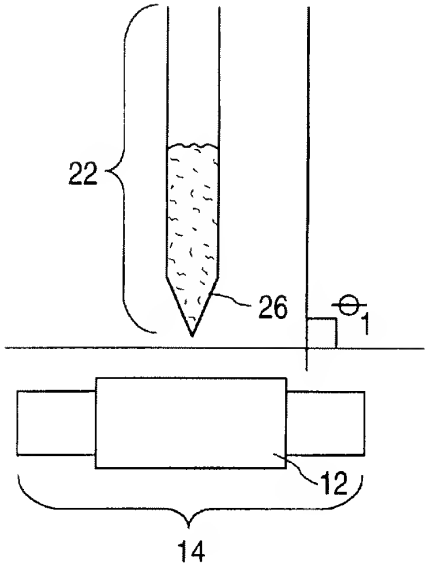



Figure 6B

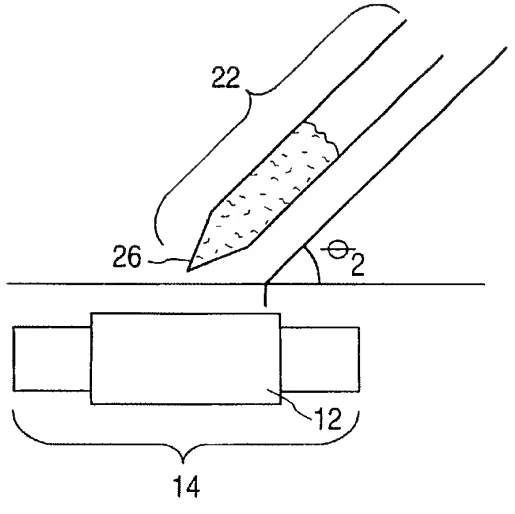



Figure 6C

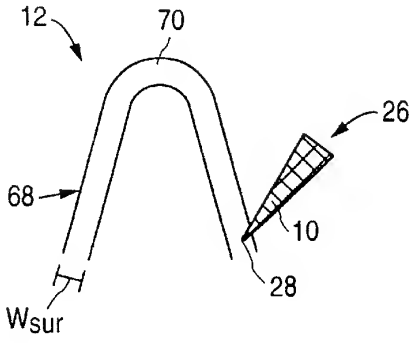



Figure 7A

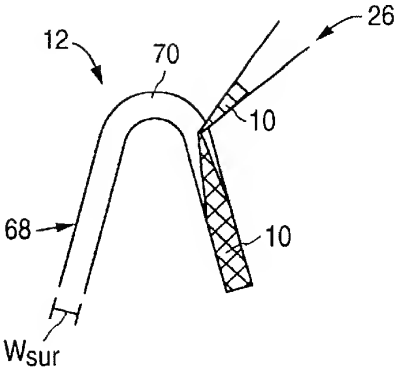



Figure 7B

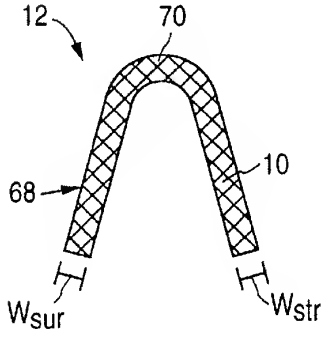



Figure 8A

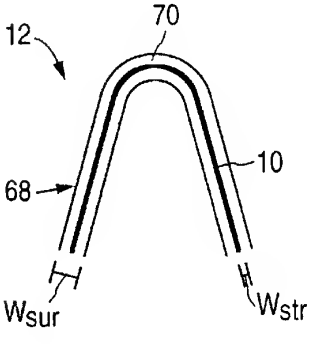



Figure 8B

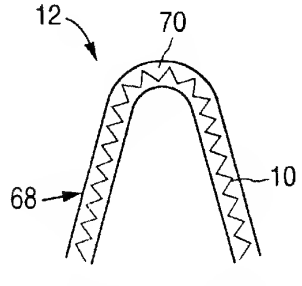



Figure 8C

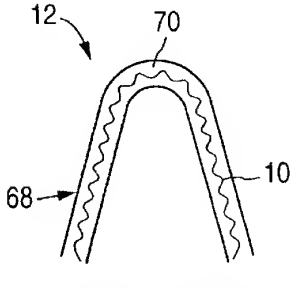



Figure 8D

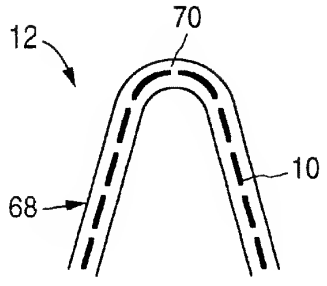



Figure 8E

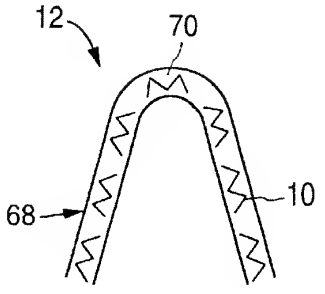



Figure 8F

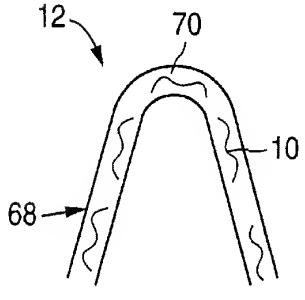



Figure 8G

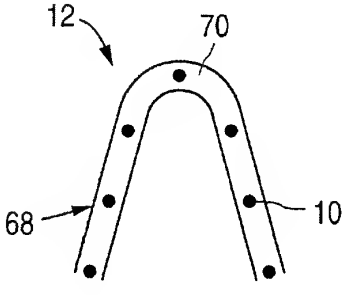



Figure 8H

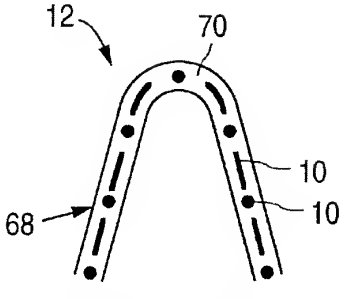



Figure 8I

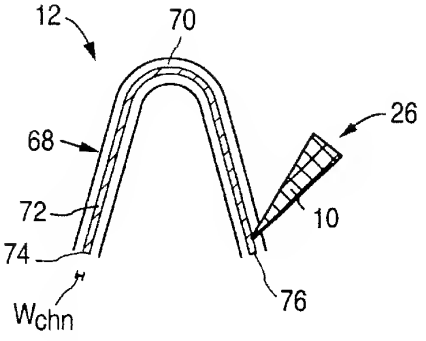



Figure 9A

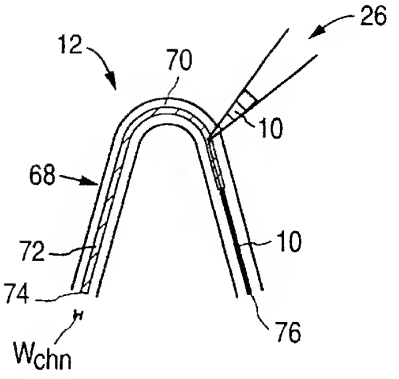



Figure 9B

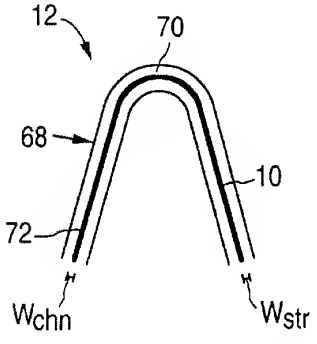



Figure 10A

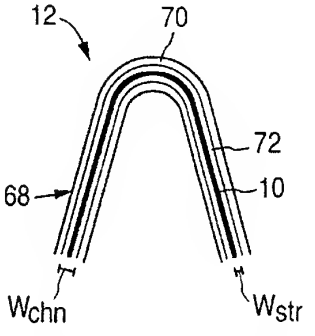



Figure 10B

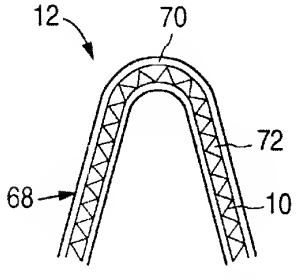



Figure 10C

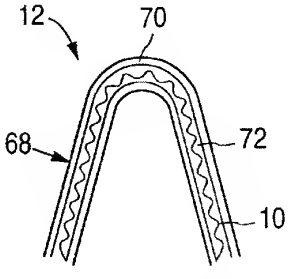



Figure 10D

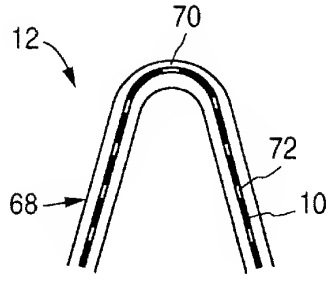



Figure 10E

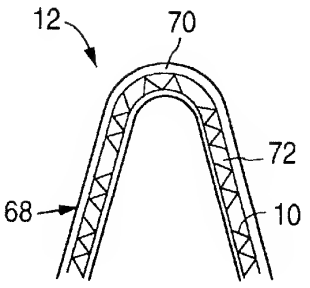



Figure 10F

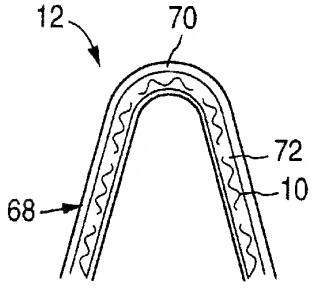



Figure 10G

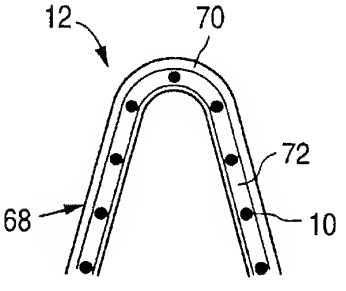



Figure 10H

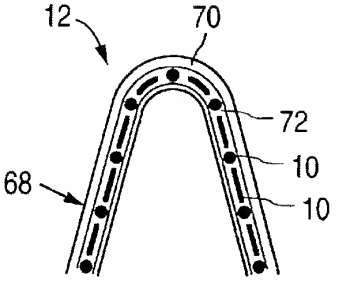



Figure 10I

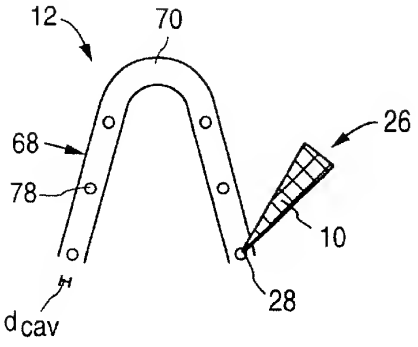



Figure 11A

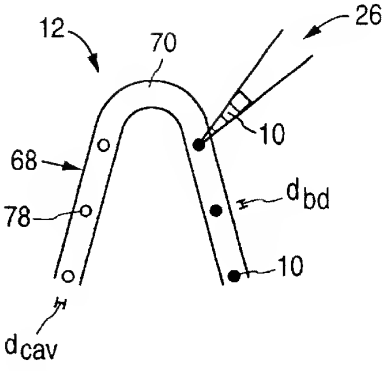



Figure 11B

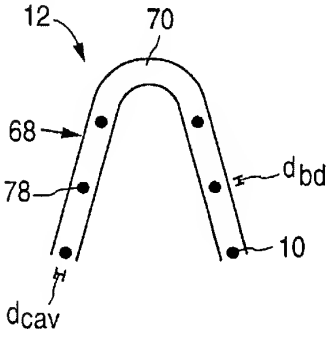



Figure 12A

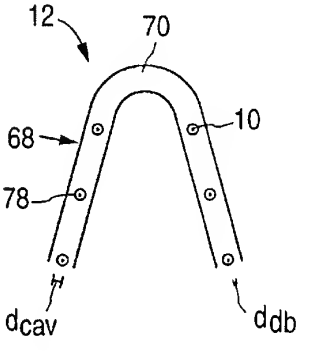



Figure 12B

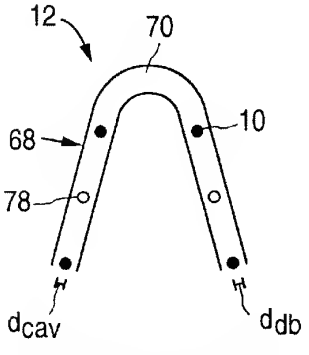



Figure 12C

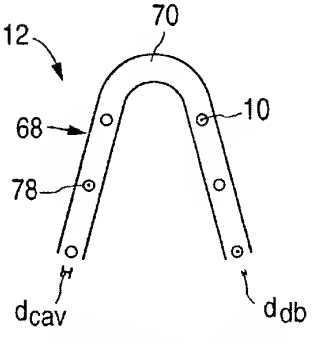



Figure 12D

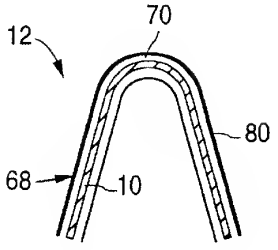



Figure 13A

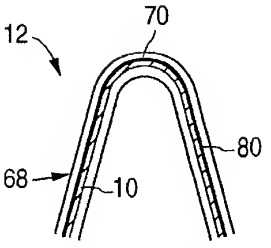



Figure 13B

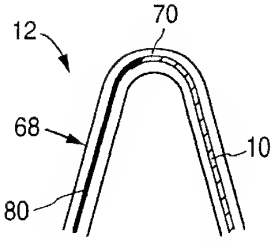



Figure 13C

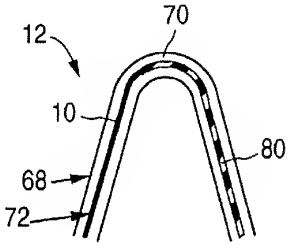



Figure 13D

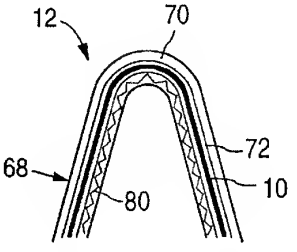



Figure 13E

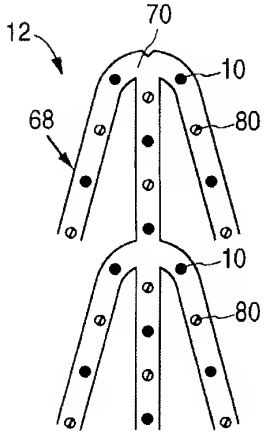



Figure 13F

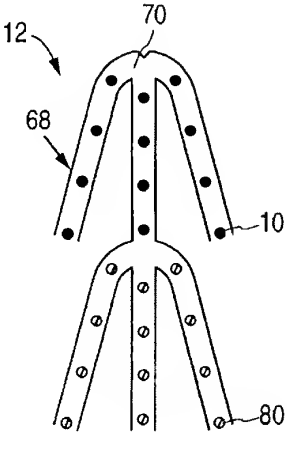



Figure 13G

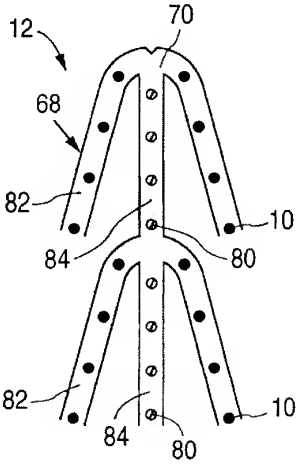



Figure 13H

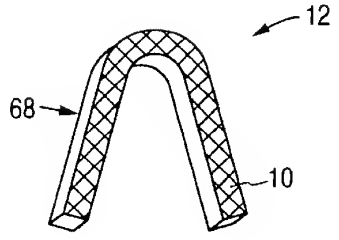



Figure 14A

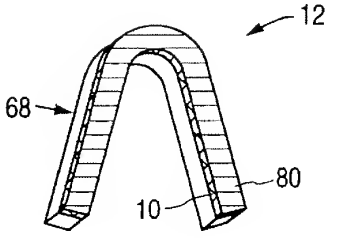



Figure 14B

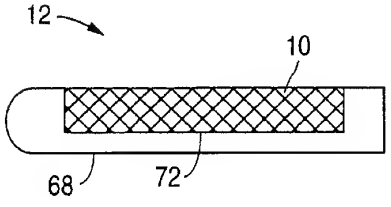



Figure 14C

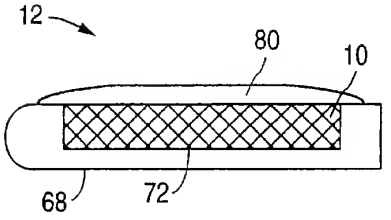



Figure 14D

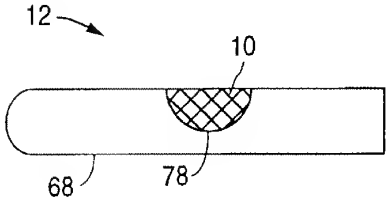



Figure 14E

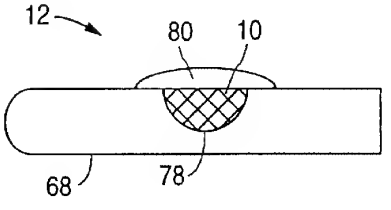



Figure 14F

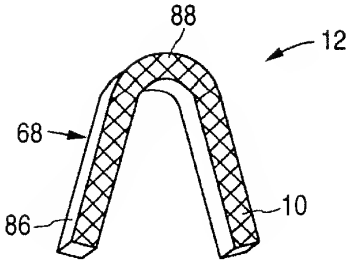



Figure 15A

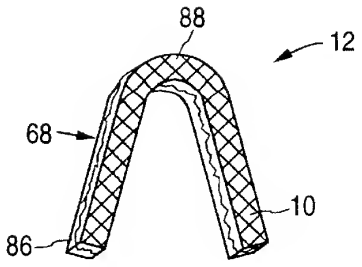



Figure 15B

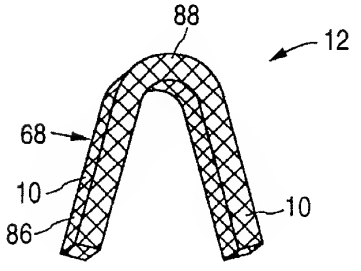



Figure 15C

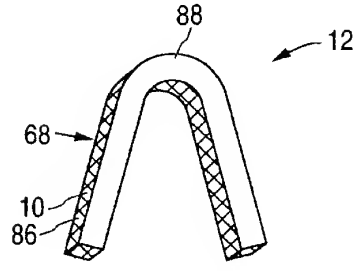



Figure 15D

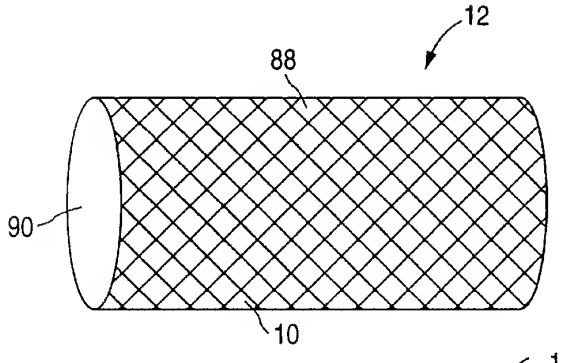



Figure 16A

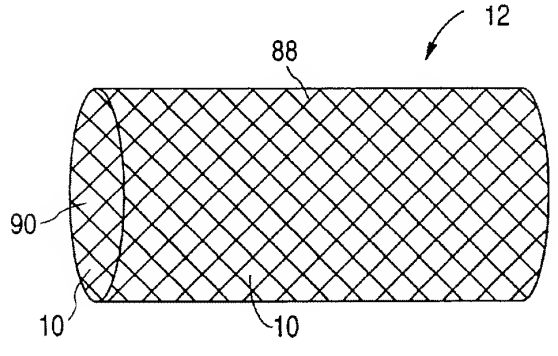



Figure 16B

# APPARATUS AND METHOD FOR DEPOSITING A COATING ONTO A SURFACE OF A PROSTHESIS

## BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to implantable devices, such as an expandable intraluminal prosthesis, one example of which includes a stent. More particularly, the invention is directed to an apparatus and method for coating a prosthesis.

2. Description of the Related Art

Percutaneous transluminal coronary angioplasty (PTCA) is a procedure for treating heart disease. A catheter assembly having a balloon portion is introduced percutaneously into the cardiovascular system of a patient via the brachial or femoral artery. The catheter assembly is advanced through the coronary vasculature until the balloon portion is positioned across the occlusive lesion. Once in position across the lesion, the balloon is inflated to a predetermined size to radially compress against the atherosclerotic plaque of the lesion to remodel the vessel wall. The balloon is deflated to a smaller profile to allow the catheter to be withdrawn from the patient's vasculature.

A problem associated with the above procedure includes formation of intimal flaps or torn arterial linings which can collapse and occlude the conduit after the balloon is deflated. Moreover, thrombosis and restenosis of the artery may develop over several months after the procedure, which may require another angioplasty procedure or a surgical by-pass operation. To reduce the partial or total occlusion of the artery by the collapse of arterial lining and to reduce the chance of the development of thrombosis and restenosis, an expandable intraluminal prosthesis, one example of which includes a stent, is implanted in the lumen to maintain the vascular patency. Stents are scaffoldings, usually cylindrical or tubular in shape, which function to physically hold open and, if desired, to expand the wall of the passageway. Typically stents are capable of being compressed for insertion through small cavities via small catheters, and expanded to a larger diameter once at the desired location. Examples in patent literature disclosing stents which have been successfully applied in PTCA procedures include U.S. Pat. No. 4,733,665 issued to Palmaz, U.S. Pat. No. 4,800,882 issued to Gianturco, and U.S. Pat. No. 4,886,062 issued to Wiktor.

To treat the damaged vasculature tissue and assist prevention of thrombosis and restenosis, there is a need for administrating therapeutic substances to the treatment site. For example, anticoagulants, antiplatelets and cytostatic agents are commonly used to prevent thrombosis of the coronary lumen, to inhibit development of restenosis, and to reduce post-angioplasty proliferation of the vascular tissue, respectively. To provide an efficacious concentration to the treated site, systemic administration of such medication often produces adverse or toxic side effects for the patient. Local delivery is a preferred method of treatment in that smaller total levels of medication are administered at a specific site in comparison to larger overall dosages that are applied systemically. Local delivery produces fewer side effects and achieves more effective results.

One commonly applied technique for the local delivery of a drug is through the use of a polymeric carrier coated onto the surface of a stent, as disclosed in U.S. Pat. No. 5,464,650 issued to Berg et al. Berg disclosed applying to a stent body a solution which included a specified solvent, a specified polymer dissolved in the solvent, and a therapeutic substance dispersed in the blend. The solvent was allowed to evaporate, leaving on the stent surface a coating of the polymer and the therapeutic substance impregnated in the polymer. As indicated by Berg, stents were immersed in the solution 12 to 15 times or sprayed 20 times.



The immersion method of coating a stent, also called dip-coating, entails submerging the entire stent, or an entire section of the stent, in a polymer solution. Similarly, spray-coating requires enveloping the entire stent, or an entire section of the stent, in a large cloud of polymeric material. One disadvantage of dip-coating and spray-coating methods is the inability to control the exact geometrical pattern of coating on the stent or section of the stent. Another shortcoming of both dip- and spray-coating is the possibility of forming web-like defects by build-up of excess polymeric material between the stent struts. Web-like defects are most prevalent in stents having tight patterns, for example coronary stents, such that the distance between the struts is very small.

Another disadvantage of both dip-coating and spray-coating stems from a low-viscosity requirement for the polymer solution in which the stent is dipped or with which the stent is sprayed. A low viscosity solution can only be achieved by using a low molecular weight polymer or by using a very low concentration of polymer in the polymer solution. Thus, both dip-coating and spray-coating methods have imposed limitations in type and concentration of applied polymers.

Other commonly applied techniques for coating a stent with a polymeric material include sputtering and gas phase polymerization. Sputtering typically involves placing a polymeric coating material target in an environment, and applying energy to the environment that hits the target and causes emission of polymeric material from the target. The polymeric emissions deposit onto the stent, forming a coating. Similarly, gas phase polymerization typically entails applying energy to a monomer in the gas phase within a system set up such that the polymer formed is attracted to a stent, thereby creating a coating around the stent.

Sputtering and gas phase polymerization have similar shortcomings. Like the dip-coating and spray-coating techniques, the sputtering and gas phase polymerization techniques do not allow control of the geometrical pattern of the coating and are quite limited in the selection of polymers that can be employed. In addition, coating a stent with a polymer and a drug at the same time via sputtering or gas phase polymerization has not been demonstrated to be effective and risks degradation of the drug. Moreover, techniques for applying a polymeric coating by sputtering or gas phase polymerization and later incorporating a drug into the applied polymeric coating are limited.

Accordingly, it is desirable to provide an improved method of applying a polymeric coating to a prosthesis. Specifically, it is desirable to provide a method of applying a polymeric coating to a prosthesis which enables control over the geometrical pattern in which a prosthesis is coated, reduces the incidence of web-like defects due to excess build-up of polymeric material, broadens the field of both the types and the concentrations of polymers which may be used to coat a prosthesis, and allows a prosthesis to be coated with a polymer and a drug at the same time.

## SUMMARY OF THE INVENTION

In accordance with one embodiment of the present invention, a method of forming a coating onto a surface of a prosthesis, such as a stent, is provided. The method comprises providing a composition and depositing the com-

position in a preselected geometrical pattern onto a first surface of the prosthesis to form the coating.

In one embodiment, the method comprises providing a composition that includes a polymer and a solvent. The polymer can constitute from about 0.1% to about 25% by weight of the total weight of the composition and the solvent can constitute from about 75% to about 99.9% by weight of the total weight of the composition.

In accordance with another embodiment, sufficient amounts of a therapeutic substance or a combination of substances are included in the composition of the polymer and the solvent. In this embodiment, the polymer can constitute from about 0.1% to about 25% by weight of the total weight of the composition. The solvent can constitute from about 49.9% to about 99.8% by weight of the total weight of the composition. The therapeutic substance can constitute from about 0.1% to about 50% by weight of the total weight of the composition.

In accordance with other embodiments, the method comprises providing a composition that includes a monomer. A monomeric composition may also include a solvent and/or a therapeutic substance. The monomeric composition may be cured to form a polymeric coating.

In accordance with other embodiments, the method comprises providing a composition that includes a polymer without a solvent. The composition may also include a therapeutic substance. The composition may be heated prior to being deposited onto the prosthesis.

In accordance with other embodiments, the method comprises providing a composition that includes a therapeutic substance. The composition may also include a solvent.

In accordance with one embodiment, depositing the composition in a preselected geometrical pattern comprises moving a dispenser assembly along a predetermined path while depositing the composition onto a stationary prosthesis. In accordance with another embodiment, depositing the composition in a preselected geometrical pattern comprises moving a holder assembly supporting the prosthesis along a predetermined path while a stationary dispenser assembly deposits the composition onto the prosthesis. In accordance with still another embodiment, depositing the composition in a preselected geometrical pattern comprises moving a holder assembly supporting the prosthesis along a first predetermined path and moving a dispenser assembly along a second predetermined path.

The preselected geometrical pattern of the composition as deposited onto a surface of the prosthesis may be a continuous stream that is either in a substantially straight line or a line that has a curved or angular pattern. The preselected geometrical pattern may also be an intermittent pattern that is in a straight line, a line that is curved or angular, or includes at least one bead.

In accordance with some embodiments, the prosthesis contains a channel extending from a first position along the first surface to a second position along the first surface and within which the composition is at least partially deposited. The preselected geometrical pattern of the composition as deposited within a channel of the prosthesis may be a continuous stream that is in a straight line or a non-straight line such as a curved line or angular line. The preselected geometrical pattern may also be an intermittent pattern that is in a straight line, a non-straight line such as a curved line or angular line, or includes at least one bead.

In accordance with other embodiments, the prosthesis contains a first cavity within the first surface of the prosthesis within which the composition is at least partially deposited. The predetermined geometrical pattern may be a bead.

In some embodiments, the application of the composition to the prosthesis is followed by the redistribution of the composition along the prosthesis. Redistribution of the composition may be accomplished by using, for example, air pressure, centrifugal force, or a second solvent.

The polymer, with or without the therapeutic substance, solidifies and adheres to the prosthesis following removal of the solvent to substantial elimination.

In accordance with another embodiment of the invention, an apparatus for depositing a composition onto a surface of a prosthesis is provided. The apparatus comprises a dispenser assembly having a nozzle for depositing a composition onto a surface of a prosthesis, a holder assembly for supporting a prosthesis, and a motion control system for either moving the dispenser assembly along a predetermined path or moving the holder assembly along a predetermined path.

The dispenser assembly may deposit the composition in a preselected geometrical pattern onto a surface of the prosthesis, at least partially within a channel formed into the prosthesis or at least partially within one or more cavities formed into the prosthesis. The preselected geometrical pattern of the deposited composition may be a continuous stream that is in a straight line or a non-straight line such as a curved line or angular line. The preselected geometrical pattern may also be an intermittent pattern that is in a straight line, a non-straight line such as a curved line or angular line, or includes at least one bead.

In accordance with some embodiments, the dispenser assembly can deposit a second composition in a preselected geometrical pattern onto the prosthesis. The first and second compositions may be in contact with one another in at least one location on the prosthesis.

In some embodiments, the dispenser assembly has a nozzle having an orifice with an orifice diameter in the range of approximately 0.5 microns to approximately 150 microns. In other embodiments, the nozzle has an orifice that can capture a last droplet of the composition to prevent lifting of the last droplet from the prosthesis. In other embodiments, the nozzle can be positioned at a 90° angle with respect to the prosthesis during deposition of the composition. In still other embodiments, the nozzle can be positioned at an angle less than 90° with respect to the prosthesis during deposition of the composition. In other embodiments, the dispenser assembly has more than one nozzle.

In accordance with some embodiments, the dispenser assembly is coupled to a delivery control system. The delivery control system may be in communication with a CPU.

In accordance with some embodiments, the motion control system is for moving the dispenser assembly along a predetermined path. The motion control system may be in communication with a CPU and may move the dispenser assembly along a predetermined path in the x, y, z, and/or rotational directions.

In accordance with other embodiments, the motion control system is for moving the holder assembly along a predetermined path. The motion control system may be in communication with a CPU and may move the holder assembly along a predetermined path in the x, y, z, and/or rotational directions.

In accordance with other embodiments, a first motion control system is for moving the dispenser assembly along a first predetermined path and a second motion control system is for moving the holder assembly along a second predetermined path.

In accordance with some embodiments, the apparatus additionally includes a feedback system. The feedback system includes a video camera for capturing an image, a lens system coupled to the video camera, frame grahher hardware to accept the image, and vision software to characterize the image. Image data from the video camera is fed hack to the motion control system, the dispenser assemhly, and/or the holder assemhly to direct deposition of the composition onto the surface of the prosthesis.

## BRIEF DESCRIPTION OF THE FIGURES

FIG. **1** illustrates a typical set-up of components which may be used to form a coating onto a surface of a prosthesis according to an aspect of the present invention;

FIG. **2**A illustrates a prosthesis supported by a holder assembly according to another aspect of the present invention.

FIG. **2**B illustrates a holder assembly having motion capahilities.

FIG. **3**A illustrates a dispenser assembly that is suitable for usage in depositing a coating on a prosthesis.

FIGS. **3**B and **3**C illustrate examples of a nozzle of a dispenser assembly.

FIGS. **3**D and **3**E illustrate examples of a dispenser assembly having a delivery control system.

FIG. **3**F illustrates a dispenser assembly having motion capabilities.

FIG. **3**G illustrates a dispenser assembly having a delivery control system as well as motion capabilities.

FIG. **4**A illustrates an exemplary feedback system that is suitable for usage in controlling the dispenser assemhly.

FIG. **4**B illustrates a feedback system capable of controlling the motion of a dispenser assembly.

FIG. **4**C illustrates a feedback system capable of controlling delivery of the composition from a dispenser assembly.

FIG. **4**D illustrates a feedback system capable of controlling the motion of a holder assembly.

FIGS. **5**A and **5**B illustrate examples of a heating assembly suitable for usage in drying or curing a coating on a prosthesis.

FIGS. **5**C, **5**D, and **5**E illustrate examples of a heating assembly having motion capahilities.

FIG. **6**A illustrates a magnified view of a surface of a prosthesis in relation to a nozzle of a dispenser assemhly containing a composition.

FIG. **6**B illustrates a dispenser assembly having a nozzle positioned at a 90° angle $\theta_1$ with respect to the prosthesis during deposition.

FIG. **6**C illustrates a dispenser assembly having a nozzle positioned at an angle $\theta_2$ that is less than 90° with respect to the prosthesis during deposition.

FIGS. **7**A and **7**B illustrate the application of the composition to a surface of a prosthesis.

FIG. **8**A illustrates a strut having a coating that completely covers a surface.

FIG. **8**B illustrates a strut having a continuous stream of coating that is in a straight line.

FIG. **8**C illustrates a strut having a continuous stream of coating that is in an angular linc.

FIG. **8**D illustrates a strut having a continuous stream of coating that is formed in a curved line.

FIG. **8**E illustrates a strut having an intermittent pattern of coating that is in a straight line.

FIG. **8**F illustrates an example of a strut having an intermittent pattern of coating that is applied in an angular line.

FIG. **8**G illustrates an example of a strut having an intermittent pattern of coating that is applied in a curved line.

FIG. **8**H illustrates a strut having an intermittent pattern of coating which includes beads.

FIG. **8**I illustrates a strut having an intermittent pattern of coating which includes beads and straight line streams.

FIGS. **9**A and **9**B illustrate the application of the composition into a channel within a strut.

FIG. **10**A illustrates a strut having a coating that completely fills a channel within the strut.

FIG. **10**B illustrates a strut having a continuous stream of coating that is in a straight line in a channel within the strut.

FIG. **10**C illustrates an example of a strut having a continuous stream of coating that is applied in an angular line in a channel within the strut.

FIG. **10**D illustrates an example of a strut having a continuous stream of coating that is applied in a curved line in a channel within the strut.

FIG. **10**E illustrates a strut having an intermittent pattern of coating that is in a straight line in a channel within the strut.

FIG. **10**F illustrates a strut having an intermittent pattern of coating that is applied in an angular line in a channel within the strut.

FIG. **10**G illustrates a strut having an intermittent pattern of coating that is applied in a curved line in a channel within the strut.

FIG. **10**H illustrates a strut having an intermittent pattern of coating that includes beads in a channel within the strut.

FIG. **10**I illustrates a strut having an intermittent pattern of coating that includes heads and straight line streams in a channel within the strut.

FIGS. **11**A and **11**B illustrate application of the composition into cavities within a strut.

FIG. **12**A illustrates a strut having a pattern of coating in which each cavity is filled.

FIG. **12**B illustrates a strut having a pattern of coating in which each cavity is partially filled.

FIG. **12**C illustrates a strut having a pattern of coating in which some but not all cavities are filled.

FIG. **12**D illustrates a strut having a pattern of coating in which some but not all cavities are partially filled.

FIG. **13**A illustrates a strut having a coating pattern in which a first coating does not make contact with a second coating.

FIGS. **13**B and **13**C illustrate examples of a strut having a coating pattern in which a first coating makes contact with a second coating.

FIG. **13**D illustrates a strut having a coating pattern in which a first coating and a second coating are within a channel of the strut.

FIG. **13**E illustrates a strut having a coating pattern in which a first coating is within a channel of the strut and a second coating is outside the channel of the strut.

FIG. **13**F illustrates a prosthesis having a coating pattern in which cavities having a first coating therein are in the same region of the struts as cavities having a second coating therein.

FIG. **13**G illustrates a prosthesis having a coating pattern in which cavities having a first coating therein are located in

a first strut of the prosthesis and cavities having a second coating therein are located in a different strut of the prosthesis.

FIG. **13**H illustrates a prosthesis having a coating pattern in which cavities having a first coating therein are located in the arms of the struts and cavities having a second coating therein are located in the links of the struts.

FIGS. **14**A and **14**B illustrate the coating of a strut with a first coating and a second coating that covers at least a portion of the first coating.

FIGS. **14**C and **14**D illustrate the coating of a strut with a first coating within a channel and a second coating that covers at least a portion of the first coating within the channel.

FIGS. **14**E and **14**F illustrate the coating of a strut with a first coating within a cavity and a second coating that covers at least a portion of the first coating within the cavity.

FIGS. **15**A, **15**B, and, **15**C illustrate the redistribution of the composition along a portion of the prosthesis.

FIG. **15**D illustrates a portion of a prosthesis upon which the composition has been redistributed.

FIGS. **16**A and **16**B illustrate redistribution of the composition along the prosthesis.

## DETAILED DESCRIPTION OF THE EMBODIMENTS

### Apparatus for Depositing a Composition onto a Prosthesis

Referring now to the drawings, wherein similar parts are identified by like reference numerals, FIG. **1** illustrates the various components which may be involved in the deposition of a composition **10** onto a surface of a prosthesis **12** in accordance with an aspect of the present invention. A broken line between two components in FIG. **1** represents an optional coupling which is present in some, but not all, embodiments of the deposition method. Prosthesis **12** is supported in a holder assembly **14** which may be coupled to a holder motion control system **16** through a holder driving component **18**. Holder motion control system **16** is in communication with CPU **20**. A dispenser assembly **22** includes a reservoir **24** and a nozzle **26** having an orifice **28**. Dispenser assembly **22** may be coupled to a delivery control system **30** which can be in communication with CPU **20**. Dispenser assembly **22** may also be coupled to a dispenser motion control system **32** through a dispenser driving component **34**. Dispenser motion control system **32** is in communication with CPU **20**.

Prosthesis **12** may be any suitable prosthesis, examples of which include self-expandable stents and balloon-expandable stents. Prosthesis **12** can be in an expanded or unexpanded state during processing according to the disclosed method. The underlying structure of prosthesis **12** can be virtually of any design. Prosthesis **12** can be made of a metallic material or an alloy such as, but not limited to, stainless steel, "MP35N," "MP20N," elastinite (Nitinol), tantalum, nickel-titanium alloy, platinum-iridium alloy, gold, magnesium, or combinations thereof. "MP35N" and "MP20N" are trade names for alloys of cobalt, nickel, chromium and molybdenum available from standard Press Steel Co., Jenkintown, Pa. "MP35N" consists of 35% cobalt, 35% nickel, 20% chromium, and 10% molybdenum. "MP20N" consists of 50% cobalt, 20% nickel, 20% chromium, and 10% molybdenum. Prosthesis **12** made from bioabsorbable or biostable polymers could also be used with composition **10**. A polymeric prosthesis **12** should be compatible with composition **10**. Further, in some embodiments, prosthesis **12** may include one or more channels and/or cavities formed therein.

In one embodiment, prosthesis **12** is a stent which includes a single cavity, or a plurality of cavities, formed therein. A cavity, which may also be referred to as a pore or a depot, may be formed as a laser trench on a stent by exposing the surface to an energy discharge from a laser, such as an excimer laser. Alternative methods of forming such cavities include, but are not limited to, physical and chemical etching techniques. Techniques of laser fabrication or etching to form cavities are well-known to one of ordinary skill in the art. Cavities can be formed in virtually any stent structure. Cavities are formed by a manufacturer at any preselected location and have any preselected depth, size, and geometrical configuration. The location of a cavity or cavities within a stent varies according to intended usage and application. The depth and size of a cavity typically depend on the material and dimensions of the stent and the type and amount of substances deposited within the cavity as well as on the clinical purpose and usage of the stent. The depth and size of the individual cavities formed on a single stent can vary relative to one another. Cavities may be formed in a variety of selected geometrical shapes including, but not limited to, generally cylindrical shapes, generally conical shapes, and elongated trenches.

As shown in FIG. **2**A, holder assembly **14** is used to support the above-described prosthesis **12** during deposition. A suitable holder assembly **14** allows access to the entire top surface, i.e., tissue-contacting surface, of prosthesis **12** while holding prosthesis **12** securely and without damaging prosthesis **12**. In addition, holder assembly **14** should be capable of being coupled to and controlled by holder motion control system **16**.

Holder motion control system **16** may be any suitable holder motion control system **16** coupled to holder assembly **14** through holder driving component **18** and communicating with CPU **20**. Holder motion control system **16** controls the motion of holder assembly **14** in response to commands from CPU **20**. Holder motion control system **16** should have the capability of maneuvering holder driving component **18** in the x, y, and z directions as well as providing rotational motion as indicated by arrow **36**. Holder motion control system **16** should have the capabilities of moving holder driving component **18** from a stopped position at intervals of less than 0.001 inch. Additionally, holder motion control system **16** should be capable of terminating the motion of holder driving component **18** at less than 0.001 inch from the position at which a termination signal from CPU **20** is received. Holder motion control system **16** must also be capable of following a given pattern on prosthesis **12** as selected by the user via CPU **20**.

Dispenser assembly **22** is used for a controlled delivery and deposition of composition **10** on prosthesis **12**. As shown in FIG. **3**A, dispenser assembly **22** can be a simple device consisting only of reservoir **24** which holds composition **10** prior to delivery and nozzle **26** having orifice **28** through which composition **10** is delivered. One exemplary type of dispenser assembly **22** can be an ink-jet printhead. Another exemplary type of dispenser assembly **22** can be a microinjector capable of injecting small volumes ranging from about 2 to about 70 nL, such as NanoLiter 2000 available from World Precision Instruments or Pneumatic PicoPumps PV830 with Micropipette available from Cell Technology System. Such microinjection syringes may be employed in conjunction with a microscope of suitable design.

Nozzle **26** may be permanently, removably or disposably affixed to reservoir **24**. Nozzle **26** may be of any suitable material including, but not limited to, glass, metal, sapphire, and plastics. Particular care should be taken to ensure that a glass nozzle **26** does not make contact with prosthesis **12** upon deposition of composition **10** to avoid nozzle **26** breakage. Particular care should also be taken to ensure that a plastic nozzle **26** is compatible with components of composition **10**. Nozzle **26** may be of any suitable design including, but not limited to the designs of FIGS. **3**B and **3**C. Nozzle **26** depicted in FIG. **3**C may be particularly useful for applications in which lifting of a final droplet **38** of composition **10** is desirable, as the depicted design of nozzle **26** allows the capture of final droplet **38** within orifice **28**. In addition, dispenser assembly **22** may include more than one nozzle **26**.

Orifice **28** of nozzle **26** can range in diameter from about 0.5 $\mu$m to about 150 $\mu$m. The particular size of orifice **28** depends on factors such as the constituents of composition **10**, the viscosity of composition **10** to be applied, the deposition pattern that is desired, and the type of prosthesis **12** employed. For example, a larger orifice **28** may be utilized for application of composition **10** to the entire outer surface of prosthesis **12** than the orifice **28** for the application of composition **10** into discrete channels or cavities within prosthesis **12**.

Delivery of composition **10** using dispenser assembly **22** can be achieved either passively or actively. Delivery can be achieved passively via capillary action. Alternatively, delivery can be achieved actively by applying a pressure p to composition **10** in reservoir **24** as depicted in FIG. **3**A. Air pressure may be employed to apply pressure p. Continuous air pressure is applied if deposition of a continuous stream of composition **10** is desired. Bursts of air pressure can be employed if an intermittent deposition pattern of composition **10** is desired. Active delivery may also be achieved via acoustic, ultrasonic, fluid, or any other forms of pressure known and available to one of ordinary skill in the art.

In one embodiment, delivery control system **30** is coupled to dispenser assembly **22** as depicted in FIG. **3**D. Operating parameters such as the timing, volume, and speed of both filling and delivery as well as the pressure applied may be controlled via delivery control system **30**. Operation of delivery control system **30** may be accomplished manually by the user. Alternatively, operation of delivery control system **30** may be accomplished via CPU **20** in communication with delivery control system **30** as shown in FIG. **3**E.

In another embodiment, dispenser motion control system **32** provides dispenser assembly **22** with the capability of motion as shown in FIG. **3**F. Dispenser motion control system **32** may be any suitable dispenser motion control system **32** coupled to dispenser assembly **22** through dispenser driving component **34** and communicating with CPU **20**. Dispenser motion control system **32** controls the motion of dispenser assembly **22** in response to commands from CPU **20**. Dispenser motion control system **32** should have the capability of maneuvering dispenser driving component **34** in the x, y, and z directions as well as providing rotational motion as indicated by arrow **40**. Dispenser motion control system **32** should have the capabilities of moving dispenser driving component **34** from a stopped position at intervals of less than 0.001 inch. Additionally, dispenser motion control system **32** should be capable of terminating the motion of dispenser driving component **34** at less than 0.001 inch, from the position at which a termination signal from CPU **20** is received. Dispenser motion control system **32** must also be capable of following a given pattern on prosthesis **12** as selected by the user via CPU **20**.

In another embodiment depicted in FIG. **3**G, dispenser assembly **22** is coupled to both delivery control system **30** and dispenser motion control system **32**. Thus in this embodiment, dispenser assembly **22** is capable of precise filling and delivery as well as motion in the x, y, and z directions and rotation in the direction of arrow **40**.

In some embodiments of the invention, a feedback system **42** directs the deposition pattern of composition **10** onto prosthesis **12**. FIG. **4**A illustrates an exemplary feedback system **42**. Feedback system **42** includes a video camera **44** and a lens system **46** as well as frame grabber hardware **48** and vision software **50** within CPU **20**.

Video camera **44** may be a standard charge coupled device (CCD) video camera. Video camera **44** should be of high quality. Lens system **46** is typically a set of high quality magnifying video camera lenses having a magnification of at least 1×, usefully in the range from about 3× to about 25×. Lens system **46** may have set optics or utilize a zoom lens. A zoom lens is particularly useful in applications in which a single lens system **46** is used to view images of varying sizes.

Frame grabber hardware **48** may be a PCI (peripheral channel interface) card. Suitable frame grabber hardware **48** should be capable of at least 256 discrete gray levels. Further, frame grabber hardware **48** should be capable of single frame acquisition as well as up to about 30 frames/second real time acquisition.

Vision software **50** may be Active X technology which allows vision programming across a Windows NT platform. Active X tools which may be used in the present invention include, but are not limited to, line caliper tools which measure width, edge tools which locate edges, image calculator tools which determine the difference between multiple images, and blob analysis tools which measure, quantitate and compare irregular shapes. Suitable vision software **50** should be compatible with Visual Basic or C++. Representative examples of suitable vision software **50** include XCaliper by FSI Automation, formerly by Optimus Corporation, and Cognex by Cognex Corporation.

In operation, video camera **44** and lens system **46** capture an image in real time. The captured image may be of, for example, an individual strut, a particular characteristic of a prosthesis, a unique pattern on a prosthesis, or the position of a nozzle relative to a particular location on a prosthesis. Frame grabber hardware **48** accepts the captured image either as a moving video or as a single, still frame and places the video or frame into a format which can be utilized by vision software **50**. Vision software **50** measures, adjusts, and otherwise characterizes the image and converts the data into a form that can be sent as feedback to and understood by, for example, delivery control system **30**, holder motion control system **16**, or dispenser motion control system **32**.

In one embodiment, feedback system **42** controls the deposition pattern of composition **10** on prosthesis **12** by controlling the motion of dispenser assembly **22**. In this embodiment, feedback system **42** can assess the relative locations of nozzle **26** of dispenser assembly **22** as well as of particular features of prosthesis **12** and provide feedback via CPU **20** to dispenser motion control system **32** which directs the motion of dispenser assembly **22**, as depicted in FIG. **4**B.

In an alternative embodiment, feedback system **42** controls the deposition pattern of composition **10** on prosthesis **12** by controlling the delivery of composition **10** from dispenser assembly **22**. In this embodiment, feedback system **42** can assess the relative locations of nozzle **26** of

dispenser assembly **22** as well as of particular features of prosthesis **12** and provide feedhack via CPU **20** to delivery control system **30** which directs the delivery of composition **10** from dispenser assemhly **22** onto prosthesis **12**, as depicted in FIG. **4**C.

In still another embodiment, feedhack system **42** controls the deposition pattern of composition **10** onto prosthesis **12** hy providing feedback via CPU **20** to holder motion control system **16** which directs the motion of holder assemhly **14** supporting prosthesis **12**, as depicted in FIG. **4**D.

In some emhodiments, a heating assembly **52** is used for controlled drying and/or curing of a coating on prosthesis **12**. As shown in FIG. **5**A, heating assemhly **52** can he a device including a heat conduit **54**, a heating nozzle **56** having an orifice **58** through which heat is delivered, and a heating control system **60**.

Heat conduit **54** delivers heat from heating control system **60** to heating nozzle **56**. Heat conduit **54** may be permanently affixed to heating control system **60** or removahle. Heat conduit **54** may he of any suitable material including, but not limited to, metal, glass, and high-temperature plastic. Particular care should be taken to ensure that the material of which heat conduit **54** is made is heat-resistant.

Heating nozzle **56** may be permanently affixed to heat conduit **54**, removable, or disposable. Heating nozzle **56** may be of any suitable material including, but not limited to, metal, glass, and high-temperature plastic. Particular care should be taken to ensure that a glass heating nozzle **56** does not make contact with prosthesis **12** upon heating to avoid heating nozzle **56** breakage. Particular care should also be taken to ensure that heating nozzle **56** is heat-resistant. In addition, heating nozzle **56** may be of any suitable shape or design.

Orifice **58** of heating nozzle **56** can range in diameter from about 50 $\mu$m to about 300 $\mu$m. The particular size of orifice **58** depends on factors such as the geometries of the struts as well as the geometries of the channels and/or cavities within the struts. For example, a larger orifice **58** may be utilized for application of heat to the entire outer surface of prosthesis **12** than the orifice **58** for the application of heat over discrete channels or cavities within prosthesis **12**.

Heating control system **60** may function as both a heat source and a controller of operating parameters such as the timing and temperature of heating. Operation of heating control system **60** may he accomplished manually hy the user. Alternatively, operation of heating control system **60** may he accomplished via CPU **20** in communication with heating control system **60** as shown in FIG. **5**B. In another emhodiment, heating control system **60** is contained within delivery control system **30** described ahove, such that both the deposition and the heating of a composition is controlled by a single component.

In some embodiments, heat conduit **54** and thus heating nozzle **56** have automated motion capahilities. In one such embodiment, heating control system **60** provides heat conduit **54** and heating nozzle **56** with the capability of motion, as shown in FIG. **5**C. Through a heater driving component **62**, heat conduit **54** and heating nozzle **56** may he capahle of motion in the x, y, and z directions and rotation in the direction of arrow **64** and may also be capahle of following a given pattern on prosthesis **12** as selected by the user.

In an alternative embodiment depicted in FIG. **5**D, a separate heating motion control system **66** provides heat conduit **54**, and thus heating nozzle **56**, with the capability of motion. Heating motion control system **66** may be any suitahle heating motion control system **66** coupled to heating assembly **52** through heater driving component **62**. Heating motion control system **66** may be in communication with CPU **20**, such that heating motion control system **66** controls the motion of heat conduit **54** and heating nozzle **56** in response to commands from CPU **20** as shown in FIG. **5**E. In such embodiments, heat conduit **54** and heating nozzle **56** may be capahle of motion in the x, y, and z directions and rotation in the direction of arrow **40** and may also he capable of following a given pattern on prosthesis **12** as selected hy the user. In still another emhodiment, heating motion control system **66** is contained within dispenser motion control system **32** described above, such that the motions of both dispenser assembly **22** and heating assembly **52** are controlled hy a single component.

In yet another embodiment, feedback system **42** directs the application of heat hy heating assemhly **52** to composition **10** along the preselected geometrical pattern in which composition **10** was deposited.

## Composition

Composition **10** to be deposited onto prosthesis **12** is prepared by conventional methods wherein all components are combined and blended. More particularly, in accordance with one example, a predetermined amount of a polymer is added to a predetermined amount of a solvent. The addition of polymer may he conducted at ambient pressure and under anhydrous atmosphere. If necessary, gentle heating and stirring and/or mixing can be employed to effect dissolution of the polymer into the solvent, for example about 12 hours in a water bath at about 60° C. The term polymer is intended to include a product of a polymerization reaction inclusive of homopolymers, copolymers, terpolymers, etc., whether natural or synthetic, including random, alternating, block, graft, crosslinked, blends, compositions of blends and variations thereof. The polymer may be in true solution or saturated in the hlended composition. The polymer may also he suspended as particles or supersaturated in the composition. In applications using nozzle **26** having a small diameter orifice **28** for applying composition **10** to prosthesis **12**, small polymer particles are to he suspended. Large coagulated polymeric particles, for example larger than the diameter of orifice **28**, can clog nozzle **26**. Supersaturation of the polymer can adversely affect the flow of composition **10** through nozzle **26** having a small diameter orifice **28** which can result in non-uniformity of the coating on prosthesis **12**.

The polymer should be hiocompatible, for example a polymeric material which, in the amounts employed, is non-toxic and chemically inert as well as substantially non-immunogenic and non-inflammatory. Suitahle polymeric materials can include, but are not limited to, polycaprolactone (PCL), poly-D,L-lactic acid (DL-PLA), poly-L-lactic acid (L-PLA), poly(lactide-co-glycolide), poly (hydroxyhutyrate), poly(hydroxyhutyrate-co-valerate), polydioxanone, polyorthoester, polyanhydride, poly (glycolic acid), poly(glycolic acid-cotrimethylene carbonate), polyphosphoester, polyphosphoester urethane, poly (amino acids), cyanoacrylates, poly(trimethylene carhonate), poly(iminocarhonate), copoly(ether-esters), polyalkylene oxalates, polyphosphazenes, polyiminocarbonates, and aliphatic polycarbonates, fihrin, fihrinogen, cellulose, starch, collagen, Parylene®, Parylast®, polyurethane, polyethylene, polyethylene teraphthalate, ethylene vinyl acetate, ethylene vinyl alcohol, silicone, polyethylene oxide, polyhutylene terepthalate (PBT)-co-PEG, PCL-co-PEG, PLA-co-PEG, polyacrylates, polyoxaesters, polyvinyl pyrrolidone (PVP), polyacrylamide (PAAm), and combinations thereof.

The solvent can be any single solvent or a combination of solvents capable of dissolving the polymer. The particular solvent or combination of solvents selected is dependent on factors such as the material from which prosthesis **12** is made and the particular polymer selected. Representative examples of suitable solvents include aliphatic hydrocarbons, aromatic hydrocarbons, alcohols, ketones, dimethyl sulfoxide (DMSO), tetrahydrofuran (THF), dihydrofuran (DHF), dimethylacetamide (DMAC), acetates and combinations thereof.

Typically, the polymer can include from about 0.1% to about 25% by weight of the total weight of composition **10**. Typically, the solvent can include from about 75% to about 99.9% by weight of the total weight of composition **10**. A specific weight ratio is dependent on factors such as the material from which prosthesis **12** is made, the geometrical structure of prosthesis **12**, the particular polymer or combination of polymers selected, the particular solvent or combination of solvents selected, and the solubility of the selected polymer(s) in the selected solvent(s).

In accordance with another embodiment, sufficient amounts of a therapeutic substance or a combination of substances are dispersed in the blended composition of the polymer and the solvent. In this embodiment, the polymer can include from about 0.1% to about 25% by weight of the total weight of composition **10**, the solvent can include from about 49.9% to about 99.8% by weight of the total weight of composition, and the therapeutic substance can include from about 0.1% to about 50% by weight of the total weight of composition **10**. Selection of a specific weight ratio of the polymer and the solvent is dependent on factors such as the material from which prosthesis **12** is made, the geometrical structure of prosthesis **12**, the particular polymer or combination of polymers selected, the particular solvent or combination of solvents selected, the solubility of the selected polymer(s) in the selected solvent(s), and the type and amount of therapeutic substance employed.

The particular weight percentage of a therapeutic substance mixed within composition **10** depends on factors such as the type of therapeutic substance selected, the solubility of the selected therapeutic substance, the duration of the release, the cumulative amount of release, and the release rate that is desired. The therapeutic substance should be in true solution, saturated, supersaturated, or in fine, suspended particles in the blended composition **10**. If the therapeutic substance is not completely soluble in composition **10**, operations including gentle heating, mixing, stirring, and/or agitation can be employed to effect homogeneity of the residues. In applications using nozzle **26** having a small diameter orifice **28** through which composition **10** is applied to prosthesis **12**, the therapeutic substance is to be suspended in small particles. Large coagulated therapeutic particles, for example larger than the diameter of orifice **28**, clog nozzle **26**. Supersaturation of the therapeutic substance can adversely affect the flow of composition **10** through nozzle **26** having a small diameter orifice **28** which can result in non-uniformity of the coating on prosthesis **12**.

Exposure of composition **10** to the therapeutic substance is not permitted to adversely alter the therapeutic substance's composition or characteristic. Accordingly, the particular therapeutic substance is selected for mutual compatibility with composition **10**. Therapeutic substances or agents may include, but are not limited to, antineoplastic, antimitotic, antiinflammatory, antiplatelet, anticoagulant, antifibrin, antithrombin, antiproliferative, antibiotic, antioxidant, and antiallergic substances as well as combinations thereof. Examples of such antineoplastics and/or antimitotics include paclitaxel (e.g. TAXOL® by Bristol-Myers Squibb Co., Stamford, Conn.), docetaxel (e.g. Taxotere®, from Aventis S.A., Frankfurt, Germany) methotrexate, azathioprine, vincristine, vinblastine, fluorouracil, doxorubicin hydrochloride (e.g. Adriamycin® from Pharmacia & Upjohn, Peapack N.J.), and mitomycin (e.g. Mutamycin® from Bristol-Myers Squibb Co., Stamford, Conn.) Examples of such antiplatelets, anticoagulants, antifibrin, and antithrombins include sodium heparin, low molecular weight heparins, heparinoids, hirudin, argatroban, forskolin, vapiprost, prostacyclin and prostacyclin analogues, dextran, D-phe-pro-arg-chloromethylketone (synthetic antithrombin), dipyridamole, glycoprotein IIb/IIIa platelet membrane receptor antagonist antibody, recombinant hirudin, and thrombin inhibitors such as Angiomax™ (Biogen, Inc., Cambridge, Mass.) Examples of such cytostatic or antiproliferative agents include angiopeptin, angiotensin converting enzyme inhibitors such as captopril (e.g. Capoten® and Capozide® from Bristol-Myers Squibb Co., Stamford, Conn.), cilazapril or lisinopril (e.g. Prinivil® and Prinzide® from Merck & Co., Inc., Whitehouse Station, N.J.); calcium channel blockers (such as nifedipinc), colchicine, fibroblast growth factor (FGF) antagonists, fish oil (omega 3-fatty acid), histamine antagonists, lovastatin (an inhibitor of HMG-CoA reductase, a cholesterol lowering drug, brand name Mevacor® from Merck & Co., Inc., Whitehouse Station, N.J.), monoclonal antibodies (such as those specific for Platelet-Derived Growth Factor (PDGF) receptors), nitroprusside, phosphodiesterase inhibitors, prostaglandin inhibitors, suramin, serotonin blockers, steroids, thioprotease inhibitors, triazolopyrimidine (a PDGF antagonist), and nitric oxide. An example of an antiallergic agent is permirolast potassium. Other therapeutic substances or agents which may be appropriate include alpha-interferon, genetically engineered epithelial cells, and dexamethasone. While the foregoing therapeutic substances or agents are well known for their preventative and treatment properties, the substances or agents are provided by way of example and are not meant to be limiting. Other therapeutic substances which are currently available or may be developed are equally applicable for use with the present invention. The treatment of patients using the above mentioned medicines is well known to those of ordinary skill in the art.

In another embodiment, composition **10** is a polymer or combination of polymers without a solvent. Because polymers are typically in solid form at room temperature, composition **10** may be heated prior to deposition onto prosthesis **12**. Composition **10** may also include a therapeutic substance. In embodiments including a therapeutic substance as well as polymeric material, the polymer can include from about 50% to about 99.9% by weight of the total weight of composition **10** and the therapeutic substance can include from about 0.1% to about 50% by weight of the total weight of composition **10**. Selection of a specific weight ratio is dependent on factors such as the material from which prosthesis **12** is made, the geometrical structure of prosthesis **12**, and the particular polymer or combination of polymers selected as well as the type and amount of therapeutic substance employed, the duration of the release, the cumulative amount of the release, and the release rate that is desired. Exposure of composition **10** to the therapeutic substance is not permitted to adversely alter the therapeutic substance's composition or characteristic. Accordingly, the particular therapeutic substance is selected for compatibility with the polymer. In addition, heat applied to composition **10**, such as heat employed to liquify an otherwise solid polymer prior to deposition onto prosthesis **12**, may not adversely alter the therapeutic substance's composition or characteristic.

In still another embodiment, composition **10** constitutes a monomer or combination of monomers. Composition **10** may also include a solvent. Following application of composition **10** to prosthesis **12**, the monomeric composition **10** is cured to form a polymeric coating. Curing may be accomplished photochemically using ultraviolet or visible irradiation and a photoinitiator, thermally, or by moisture curing at room temperature. The practice of these and other suitable curing procedures are well known to one of ordinary skill in the art. In embodiments including a solvent as well as monomeric material, the monomer constitutes from about 0.1% to about 50% by weight of the total weight of composition **10** and the solvent constitutes from about 50% to about 99.9% by weight of the total weight of composition **10**. Composition **10** may also include a therapeutic substance. In embodiments including a monomer and a therapeutic substance but no solvent, the monomer can include from about 50% to about 99.9% by weight of the total weight of composition **10** and the therapeutic substance can include from about 0.1% to about 50% by weight of the total weight of composition **10**. In embodiments including a solvent as well as monomeric material and a therapeutic substance, the monomer constitutes from about 0.1% to about 49.9% by weight of the total weight of the composition, the solvent constitutes from about 49.9% to about 99.8% by weight of the total weight of said composition, and the therapeutic substance constitutes from about 0.1% to about 50% by weight of the total weight of the composition. Selection of a specific weight ratio is dependent on factors such as the material from which prosthesis **12** is made, the geometrical structure of prosthesis **12**, and the particular monomer or combination of monomers selected as well as the type and amount of therapeutic substance employed, the duration of the release, the cumulative amount of the release, and the release rate that is desired. Exposure of composition **10** to the therapeutic substance is not permitted to adversely alter the therapeutic substance's composition or characteristic. Accordingly, the particular therapeutic substance is selected for compatibility with the monomer. In addition, curing the monomer may not adversely alter the therapeutic substance's composition or characteristic.

In another embodiment, composition **10** includes a therapeutic substance without a polymer. Composition **10** may also include a solvent. In embodiments including a solvent as well as a therapeutic substance, the solvent can include from about 50% to about 99.9% by weight of the total weight of composition **10** and the therapeutic substance can include from about 0.1% to about 50% by weight of the total weight of composition **10**. Selection of a specific weight ratio is dependent on factors such as the material from which prosthesis **12** is made, the geometrical structure of prosthesis **12**, and the particular solvent or combination of solvents selected as well as the type and amount of therapeutic substance employed, the duration of the release, the cumulative amount of the release, and the release rate that is desired. Exposure of the solvent to the therapeutic substance is not permitted to adversely alter the substance's composition or characteristic. Accordingly, the particular therapeutic substance is selected for compatibility with the solvent.

A Method for Coating a Prosthesis

To form a coating onto a surface of prosthesis **12**, the surface of prosthesis **12** should be clean and free from contaminants that may be introduced during manufacturing. However, the surface of prosthesis **12** requires no particular surface treatment to retain the applied coating.

In one set of embodiments, holder assembly **14** moves along a predetermined path while dispenser assembly **22** remains stationary during deposition of composition **10**. In these embodiments, nozzle **26** of dispenser assembly **22** is positioned at a load position over, or in contact with, a strut **68** of prosthesis **12** as shown in FIG. **6**A. As composition **10** is deposited, dispenser assembly **22** remains stationary while prosthesis **12** in holder assembly **14** is moved via holder motion control system **16** along a predetermined path beneath the stationary nozzle **26**, thereby causing composition **10** to be deposited in a preselected geometrical pattern on prosthesis **12**.

In another set of embodiments, dispenser assembly **22** moves along a predetermined path while holder assembly **14** remains stationary during deposition of composition **10**. In such embodiments, nozzle **26** of dispenser assembly **22** is positioned at a load position over, or in contact with, strut **68** of prosthesis **12** as shown in FIG. **6**A. As composition **10** is deposited, holder assembly **14** remains stationary while dispenser assembly **22** is moved via dispenser motion control system **32** along a pre-determined path around the stationary prosthesis **12**, thereby causing the composition **10** to be deposited in a preselected geometrical pattern on prosthesis **12**.

In still another set of embodiments, both dispenser assembly **22** and holder assembly **14** move along respective predetermined paths during deposition of composition **10**. By example and not limitation, dispenser assembly **22** may move in the x, y, and z directions while holder assembly **14** may move rotationally. In these embodiments, nozzle **26** of dispenser assembly **22** is positioned at a load position over, or in contact with, strut **68** of prosthesis **12** as shown in FIG. **6**A. As composition **10** is deposited, holder assembly **14** is moved via holder motion control system **16** along a predetermined path while dispenser assembly **22** is moved via dispenser motion control system **32** along another predetermined path, thereby causing composition **10** to be deposited in a preselected geometrical pattern on prosthesis **12**.

As depicted in FIG. **6**B, nozzle **26** may be positioned at an angle $\theta_1$ of about 90° with respect to prosthesis **12** during deposition of composition **10**. Alternatively, nozzle **26** may be positioned at an angle $\theta_2$ of less than 90° with respect to prosthesis **12** during deposition of composition **10** as depicted in FIG. **6**C.

Composition **10** may be applied along struts **68** of prosthesis **12** in a variety of deposition patterns and having a variety of thicknesses. FIGS. **7**A–**7**B illustrate the deposition of composition **10** along a surface **70** having a surface width $w_{sur}$ in accordance with one set of embodiments of the method. In FIG. **7**A, nozzle **26** containing composition **10** is positioned over, or in contact with, strut **68** of prosthesis **12**. In FIG. **7**B, the deposition of composition **10** in a preselected geometrical pattern continues along surface **70** of prosthesis **12**. When deposition onto strut **68** of prosthesis **12** is complete, a continuous stream of composition **10** having a selected stream width $w_{str}$ may follow at least a portion of surface **70** of prosthesis **12**. The stream width $w_{str}$ may, for example, be equal to or larger than the surface width $w_{sur}$ such that the continuous stream covers surface **70** completely as depicted in FIG. **8**A. Alternatively, the stream width $w_{str}$ may be smaller than the surface width $w_{sur}$ such that the continuous stream partially covers a portion of surface **70** in a straight line as depicted in FIG. **8**B, in an angular line as depicted in FIG. **8**C, or in a curved line as depicted in FIG. **8**D. The resulting preselected geometrical pattern of composition **10** may be repeated on a single strut **68** or on more than one strut **68** of prosthesis **12**.

In an alternative set of embodiments, composition **10** may be deposited in an intermittent pattern along at least a portion of surface **70** of prosthesis **12**. Delivery of an intermittent pattern may be achieved where delivery is started and stopped at predetermined intervals to yield patterns that are in a straight line as depicted in FIG. **8**E, patterns that are in an angular line as depicted in FIG. **8**F, patterns that are in a curved line as depicted in FIG. **8**G, patterns that include at least one bead along surface **70** of prosthesis **12** as depicted in FIG. **8**H, or combinations thereof as depicted in FIG. **8**I. The resulting preselected geometrical pattern of composition **10** may be repeated on a single strut **68** or on more than one strut **68** of prosthesis **12**.

In another set of embodiments, prosthesis **12** includes a channel **72** having a channel width $w_{chn}$ and extending from a first position **74** to a second position **76** on strut **68** as shown in FIGS. **9**A–**9**B. In FIG. **9**A, nozzle **26** containing composition **10** is positioned over, or in contact with, channel **72**. In FIG. **9**B, the deposition of composition **10** in a preselected geometrical pattern continues at least partially along channel **72**. When deposition into channel **72** is complete, a continuous stream of composition **10** having a selected stream width $w_{str}$ may fill at least a portion of channel **72**. The stream width $w_{str}$ may, for example, be equal to or larger than channel width $w_{chn}$ such that channel **72** is filled completely as depicted in FIG. **10**A. Alternatively, the stream width $w_{str}$ may be smaller than the channel width $w_{chn}$ so as to partially fill channel **72** with a continuous stream that is substantially in a straight line as depicted in FIG. **10**B, in an angular line as depicted in FIG. **10**C, or in a curved line as depicted in FIG. **10**D. The resulting preselected geometrical pattern of composition **10** may be repeated on a single strut **68** or on more than one strut **68** of prosthesis **12**.

In an alternative set of embodiments, deposition of an intermittent pattern of composition **10** may be achieved where delivery is started and stopped at predetermined intervals. Resulting patterns at least partially within channel **72** may be in a straight line as depicted in FIG. **10**E, in an angular line as depicted in FIG. **10**F, in a curved line as depicted in FIG. **10**G, include at least one bead as depicted in FIG. **10**H, or a combination thereof as depicted in FIG. **10**I. The resulting preselected geometrical pattern of composition **10** may be repeated on a single strut **68** or on more than one strut **68** of prosthesis **12**.

In still another set of embodiments, composition **10** is applied into cavities **78** within surface **70** of prosthesis **12** having a cavity diameter $d_{cav}$ as depicted in FIGS. **11**A–**11**B. In FIG. **11**A, nozzle **26** containing composition **10** is positioned over, or in contact with, cavity **78** within strut **68** of prosthesis **12**. Cavity **78** may be loaded with composition **10** in a preselected geometrical pattern such as, but not limited to, a bead having a selected bead diameter $d_{bd}$. The selected bead diameter $d_{bd}$ may be equal to, larger than or smaller than cavity diameter $d_{cav}$. The filling process may continue as shown in FIG. **11**B until a preselected number and geometrical pattern of cavities **78** within prosthesis **12** have been at least partially filled with composition **10**. FIG. **12**A depicts a deposition pattern in which every cavity **78** is completely filled with composition **10**. FIG. **12**B depicts a deposition pattern in which every cavity **78** is partially filled with composition **10**. Alternatively, composition **10** may be deposited in any number of patterns in which some, but not all, cavities **78** within prosthesis **12** are at least partially filled, as depicted in FIGS. **12**C and **12**D. The resulting preselected geometrical pattern of composition **10** may be repeated on a single strut **68** or on more than one strut **68** of prosthesis **12**.

In some embodiments, prosthesis **12** may be exposed to a drying or curing procedure following the deposition of composition **10** outo prosthesis **12**. In embodiments in which composition **10** includes a solvent, for example, the solvent may be removed from composition **10** on prosthesis **12** by allowing the solvent to evaporate. The evaporation can be induced by heating prosthesis **12** at a predetermined temperature for a predetermined period of time. For example, prosthesis **12** can be heated at a temperature of about 60° C. to about 70° C. for about 2 hours to about 24 hours. The heating can be conducted in an anhydrous atmosphere and at ambient pressure. The heating can be conducted under a vacuum condition. Alternatively, an extraction solvent may be employed to remove the solvent from composition **10** on prosthesis **12** so long as the extraction solvent is mutually compatible with the polymer and with the therapeutic substance and does not adversely affect the coating. The use of an extraction solvent in this manner is well known to those of ordinary skill in the art who understand that essentially all of the solvent will be removed from composition **10** but traces or residues can remain blended with the polymer. Following removal of the solvent, a coating remains on prosthesis **12** or a portion thereof.

In other embodiments, such as, but not limited to, embodiments in which composition **10** includes a monomer, prosthesis **10** is exposed to a curing procedure following application of composition **10** to prosthesis **12**. Curing may be accomplished photochemically using ultraviolet or visible irradiation and a photoinitiator, thermally, or by moisture curing at room temperature. The practice of these and other suitable curing procedures are well known to one of ordinary skill in the art. Following the curing procedure, a coating remains on prosthesis **12** or a portion thereof.

In still other embodiments in which a drying or curing procedure is used, heating assembly **52** is employed to facilitate localized heating of composition **10** only in the preselected geometrical pattern in which composition **10** was deposited, rather than heating of the entire prosthesis **12** as in the conventional drying and curing methods described above. In such embodiments, heating nozzle **56** is positioned directly over the initial area in which composition **10** is to be dried or cured. Heat having a temperature ranging from about 35° C. to about 100° C. is then delivered to composition **10** for approximately 0.1 seconds to approximately 5 seconds. The temperature and time should be sufficient to dry or cure composition **10** without degrading the components of composition **10**.

As heat is delivered, heating nozzle **56** may remain stationary while prosthesis **12** in holder assembly **14** is moved via holder motion control system **16** along a predetermined path beneath the stationary heating nozzle **56**, thereby causing heat to be delivered following the preselected geometrical pattern of the composition on prosthesis **12**. Alternatively, holder assembly **14** remains stationary while heating nozzle **56** is moved via heating motion control system **66** or heating control system **60** along a predetermined path around the stationary prosthesis **12**, thereby causing heat to be delivered following the preselected geometrical pattern of the composition on prosthesis **12**. In another embodiment, both heating nozzle **56** and holder assembly **14** may move along respective predetermined paths during delivery of heat, thereby causing heat to be delivered following the preselected geometrical pattern of the composition on prosthesis **12**. In still another embodiment, heating nozzle **56** may be moved manually by the user along a predetermined path during delivery of heat, thereby causing heat to be delivered following the prese-

lected geometrical pattern of the composition on prosthesis **12**. Following the heating procedure via heating assembly **52**, a coating remains on prosthesis **12** or a portion thereof.

In some embodiments of the method, a second composition **80** can be deposited onto prosthesis **12** concurrent with or subsequent to the application of composition **10** to prosthesis **12**. Second composition **80** may differ from first composition **10** in the particular polymer(s) or monomer(s) selected, the concentration of polymer(s) or monomer(s), the particular therapeutic substance(s) selected, the concentration of the therapeutic substance(s), or a combination thereof. Second composition **80** may be deposited to avoid contact with composition **10**, as depicted in FIG. **13**A. Second composition **80** may also be deposited adjacent to composition **10**, as depicted in FIGS. **13**B and **13**C.

In another embodiment in which second composition **80** is employed, first composition **10** and second composition **80** are both deposited within a channel **72** of prosthesis **12**, as depicted in FIG. **13**D. Alternatively, first composition **10** may be deposited at least partially within channel **72** of prosthesis **12** while second composition **80** is deposited completely outside of channel **72** of prosthesis **12**, as depicted in FIG. **13**E.

In still other embodiments in which second composition **80** is employed, first composition **10** is deposited at least partially within some depots or cavities **78** of prosthesis **12** while second composition **80** is deposited at least partially within other depots or cavities **78** of prosthesis **12**. First composition **10** may be deposited in depots or cavities **78** located in the same region as those depots or cavities **78** having second composition **80** deposited therein, as depicted in FIG. **13**F. Alternatively, first composition **10** may be deposited in depots or cavities **78** located in a different region than those depots or cavities **78** having second composition **80** deposited therein. By example and not limitation, first composition **10** and second composition **80** may be deposited in depots or cavities **78** located in different struts **68** of prosthesis **12** as depicted in FIG. **13**G. Alternatively, first composition **10** may be deposited in depots or cavities **78** within arms **82** of struts **68** while second composition **80** may be deposited in depots or cavities **78** within links **84** of struts **68** as depicted in FIG. **13**H.

In another set of embodiments in which second composition **80** is employed, second composition **80** is deposited to at least partially cover first composition **10**. In one such embodiment, first composition **10** is deposited on prosthesis **12** as shown in FIG. **14**A. Second composition **80** is then deposited to at least partially cover first composition **10** as depicted in FIG. **14**B. In an alternative embodiment, first composition **10** is deposited within channel **72** of prosthesis **12** as shown in FIG. **14**C. Second composition **80** is then deposited to at least partially cover first composition **10** within channel **72** as depicted in FIG. **14**D. In still another embodiment, first composition **10** is deposited within at least one depot or cavity **78** of prosthesis **12** as shown in FIG. **14**E. Second composition **80** is then deposited to at least partially cover first composition **10** within depot or cavity **78** as depicted in FIG. **14**F.

In each of the above-described embodiments in which second composition **80** is deposited to at least partially cover first composition **10**, a drying or curing procedure may be employed. The drying or curing procedure may be carried out following the deposition of first composition **10** and prior to the deposition of second composition **80**. In other embodiments, the drying or curing procedure may be carried out following the deposition of second composition **80**. In still other embodiments, the drying or curing procedure is carried out both after the deposition of first composition **10** and after the deposition of second composition **80**. In some embodiments, first composition **10** and/or second composition **80** is dried or cured using procedures that are well known to one of ordinary skill in the art, such as those described above. In an alternative set of embodiments, first composition **10** and/or second composition **80** is dried or cured using heating assembly **52** as described above.

In still other embodiments of the method, composition **10** can be redistributed on prosthesis **12** following the application of composition **10** to prosthesis **12** and prior to any drying or curing procedure. In the embodiments depicted in FIGS. **15**A–**15**D, composition **10** can be redistributed along sides **86** of strut **68**. FIG. **15**A illustrates strut **68** of prosthesis **12** subsequent to the deposition of composition **10** onto outer surface **88** of strut **68** and prior to the removal of solvent from composition **10**. In FIG. **15**B, composition **10** is beginning to be redistributed, as evidenced by the flow of composition **10** from outer surface **88** onto sides **86**. FIG. **15**C illustrates strut **68** on which composition **10** has been redistributed such that composition **10** coats sides **86** as well as outer surface **88** of strut **68**. Alternatively, composition **10** can be redistributed such that composition **10** coats sides **86** instead of outer surface **88** upon which composition **10** was originally deposited, as depicted in FIG. **15**D. In this alternative embodiment, essentially all of composition **10** will be redistributed from outer surface **88** to sides **86** but traces or residues can remain on outer surface **88**.

In another embodiment, composition **10** can be redistributed along an inner surface **90** of prosthesis **12** after composition **10** has been deposited and before the solvent has been removed. FIG. **16**A illustrates prosthesis **12** subsequent to the deposition of composition **10** onto outer surface **88**. FIG. **16**B illustrates prosthesis **12** after composition **10** has been redistributed such that composition **10** coats inner surface **90** as well as outer surface **88** of prosthesis **12**. In still another embodiment not depicted, composition **10** can be redistributed along both sides **86** and inner surface **90** of prosthesis **12** after composition **10** has been deposited and before the solvent has been removed.

Redistribution can be accomplished via various techniques including, but not limited to, the use of air pressure, centrifugal force, or a second solvent. Composition **10** can be directed from outer surface **88** of prosthesis **12** onto sides **86** and/or inner surface **90** by passing air across composition **10** on outer surface **88** in bursts or in a steady stream using any method known and available to one of ordinary skill in the art. Spinning prosthesis **12**, such as by centrifugation, may cause composition **10** to flow from outer surface **88** onto sides **86** and/or inner surface **90** of prosthesis **12** through centrifugal force. Application of a low viscosity solvent, for example 0.5 to 50 centipoise, to the composition-covered outer surface **88** of prosthesis **12**, can reduce the viscosity of composition **10** to readily flow along sides **86** and/or inner surface **90** of prosthesis **12**. Following redistribution of composition **10**, the solvent(s) may be removed from composition **10** as described above to form a coating on prosthesis **12**.

By way of example, and not limitation, the coating formed on prosthesis **12** can have a thickness of about 0.01 microns to about 20 microns. The particular thickness of the coating is dependent on factors such as the desired amount of therapeutic substance, if any, to be incorporated into the coating, the desired use of the coating and the type of procedure for which prosthesis **12** is employed.

Method of Use

In accordance with the above described methods, therapeutic substances can be applied to a prosthesis, for example a stent, retained on the stent during delivery and expansion of the stent, and released at a desired control rate and for a predetermined duration of time at the site of implantation. A stent having the above described medicated coating is useful for a variety of medical procedures, including, by way of example, treatment of obstructions caused by tumors in bile ducts, esophagus, and trachea/bronchi. A stent having the above described medicated coating is particularly useful for treating occluded regions of blood vessels caused by formation of intimal flaps or torn arterial linings, thrombosis, and restenosis. Stents may be placed in a wide array of blood vessels, both arteries and veins. Representative examples of sites include the iliac, renal, and coronary arteries.

Briefly, an angiogram is performed to determine the appropriate positioning for stent therapy. An angiogram is typically accomplished by injecting a radiopaque contrasting agent through a catheter inserted into an artery or vein as an x-ray is taken. A guidewire is advanced through the lesion or proposed site of treatment. Over the guidewire is passed a delivery catheter which allows a stent in a collapsed configuration to be inserted into the passageway. The delivery catheter is inserted either percutaneously or by surgery into the femoral artery, brachial artery, femoral vein, or brachial vein, and advanced into the appropriate blood vessel by steering the catheter through the vascular system under fluoroscopic guidance. A stent having the above described coating may be expanded at the desired area of treatment. A post insertion angiogram may also be utilized to confirm appropriate positioning.

While particular embodiments of the present invention have been shown and described, it will be obvious to those having ordinary skill in the art that changes and modifications can be made without departing from this invention in its broader aspects and, therefore, the appended claims are to encompass within their scope all such changes and modifications as fall within the true spirit and scope of this invention.

What is claimed is:

1. A method of forming a coating on a stent, comprising:

(a) positioning a nozzle in close proximity to or in contact with a stent, the stent having a scaffolding network including gaped regions; and

(b) moving the nozzle from a first position to a second position while maintaining the nozzle in close proximity to or in contact with the scaffolding network to deposit a coating material on at least a portion of the scaffolding network, wherein the nozzle is moved along the pattern of the scaffolding network between the first position and the second position to avoid any significant application of the coating material in the gaped regions.

2. The method of claim 1, wherein the stent is maintained in a stationary position.

3. The method of claim 1, wherein the stent is moved in concert with the nozzle for maintaining the positioning of the nozzle along the pattern of the scaffolding network.

4. The method of claim 1, where the coating material is selected from a group of polymers, therapeutic agents, or mixtures thereof.

5. The method of claim 1, additionally including applying heat to the coating material for solidifying the coating material on the stent, wherein the heat is applied to and concentrated on the region where the coating material has been applied to the scaffolding network so as to avoid application of the heat to the other areas of the scaffolding network.

6. The method of claim 1, wherein the movement of the nozzle is controlled by a central processing unit.

7. The method of claim 1, wherein the movement of the nozzle is controlled by a central processing unit and a feedback system for providing information about the pattern of the scaffolding network or the positioning of the nozzle to the central processing unit.

8. The method of claim 1, wherein the pattern from the first position to the second position is a non-linear path along which the nozzle is moved.

9. The method of claim 1, wherein the nozzle is at an angle of less than 90 degrees to the surface of the scaffolding network.

10. The method of claim 1, additionally including adjusting the flow rate of the coating material out from the nozzle and the speed of the nozzle from the first position to the second position so as to prevent any significant overflow of the coating material off the scaffolding network.

11. The method of claim 1, wherein the nozzle is capable of moving in intervals of less than 0.1 inches.

12. The method of claim 1, wherein the nozzle is capable of moving in intervals of less than 0.001 inches.

13. A method of forming a coating on a stent, comprising:

(a) positioning a nozzle in close proximity to or in contact with a stent, the stent having a scaffolding network including gaped regions; and

(b) moving the stent from a first position to a second position while maintaining the scaffolding network in close proximity to or in contact with the nozzle to deposit a coating material on at least a portion of the scaffolding network, wherein the nozzle is maintained along the pattern of the scaffolding network between the first position and the second position to avoid any significant application of the coating material in the gaped regions.

14. The method of claim 13, wherein the nozzle is held in a stationary position.

15. The method of claim 13, wherein the nozzle is capable of rotating about the circumference of the stent.

16. The method of claim 13, wherein the nozzle is capable of moving in concert with the stent for maintaining the positioning of the nozzle along the pattern of the scaffolding network.

17. The method of claim 13, where the coating material is selected from a group of polymers, therapeutic agents, or a mixture thereof.

18. The method of claim 13, additionally including applying heat to the coating material for solidifying the coating material on the stent, wherein the heat is applied to and concentrated on the region where the coating material has been applied to the scaffolding network so as to avoid application of the heat to the other areas of the scaffolding network.

19. The method of claim 13, wherein the movement of the stent is controlled by a central processing unit.

20. The method of claim 13, wherein the movement of the stent is controlled by a central processing unit and a feedback system for providing information about the pattern of the scaffolding network or the positioning of the nozzle to the central processing unit.

21. The method of claim 13, wherein the pattern from the first position to the second position is a non-linear path.

22. The method of claim 13, wherein the nozzle is at an angle of less than 90 degrees to the surface of the scaffolding network.

23. The method of claim 13, additionally including adjusting the flow rate of the coating material out from the nozzle and the speed of the movement of the stent from the first position to the second position so as to prevent any significant overflow of the coating material off the scaffolding network.

24. The method of claim 13, wherein the stent is capable of being moved in intervals of less than 0.1 inches.

25. The method of claim 13, wherein the stent is capable of being moved in intervals of less than 0.001 inches.

* * * * *

EVIDENCE APPENDIX "B"

US006358556B1

(12) **United States Patent**
**Ding et al.**

(10) **Patent No.: US 6,358,556 B1**
(45) **Date of Patent: *Mar. 19, 2002**

(54) **DRUG RELEASE STENT COATING**

(75) Inventors: **Ni Ding**, Plymouth, MN (US); **Michael N. Helmus**, Long Beach, CA (US)

(73) Assignee: **Boston Scientific Corporation**, Natick, MA (US)

( * ) Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/012,443**

(22) Filed: **Jan. 23, 1998**

**Related U.S. Application Data**

(60) Division of application No. 08/663,490, filed on Jun. 13, 1996, now Pat. No. 5,837,313, which is a continuation-in-part of application No. 08/526,273, filed on Sep. 11, 1995, now abandoned, and a continuation-in-part of application No. 08/424,884, filed on Apr. 19, 1995, now abandoned.

(51) **Int. Cl.**[7] ..... **B05D 3/04**; B05D 3/06; A61L 9/18

(52) **U.S. Cl.** ..... **427/2.24**; 427/2.25; 427/2.28; 427/2.3; 427/2.31; 427/496; 427/535; 427/551

(58) **Field of Search** ..... 623/1, 2, 11, 12; 424/422, 423, 424; 427/2.1, 2.24, 2.25, 2.28, 2.3, 2.31, 488, 496, 533, 535, 551

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| 3,932,627 | A | 1/1976 | Margraf |
| 4,292,965 | A | 10/1981 | Nash et al. |
| 4,613,665 | A | 9/1986 | Larm |

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| EP | 0623354 | | 11/1994 |
| EP | 0 734721 | A2 | 10/1996 |
| JP | 03-297469 | | 12/1991 |
| JP | 3297469 | A * | 12/1991 |
| JP | 06-121828 | | 6/1994 |
| JP | 08-33718 | | 2/1996 |
| WO | WO 91/12779 | | 9/1991 |
| WO | WO 92/15286 | | 9/1992 |
| WO | WO 94/21308 | | 9/1994 |
| WO | WO 94/21309 | | 9/1994 |
| WO | PCT/IB 96/00272 | | 6/1996 |

OTHER PUBLICATIONS

Baxter Healthcare Corp. Duraflo Biocompatible Treatment.

Ludwig K. von Segesser, MD., "Heparin–Bonded Surfaces in Extracorporeal Membrane Oxygenation for Cardiac Support", The Society of thoracic Surgeons, (1996).

Li–Chien Hsu, "Principles of Heparin–Coating Techniques", Perfusin 6: 209–219 (1991).

J.M. Toomasian et al., "Evaluation of Duraflo II Heparin Coating in Prolonged Extracorporeal Membrane Oxygenation", ASAIO Trans 34: 410–14 (1988).

S.D. Tong et al., "Non–Thrombogenic Hemofiltration System for Acute Renal Failure Treatment", ASAIO Trans. 38: M702–M706 (1992).

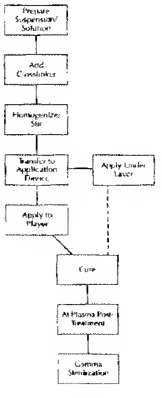
(List continued on next page.)

*Primary Examiner*—Shrive P. Beck
*Assistant Examiner*—Jennifer Kolb Michener

(57) **ABSTRACT**

A method of coating implantable open lattice metallic stent prosthesis is disclosed which includes sequentially applying a plurality of relatively thin outer layers of a coating composition comprising a solvent mixture of uncured polymeric silicone material and crosslinker and finely divided biologically active species, possibly of controlled average particle size, to form a coating on each stent surface. The coatings are cured in situ and the coated, cured prosthesis are sterilized in a step that includes preferred pretreatment with argon gas plasma and exposure to gamma radiation electron beam, ethylene oxide, steam.

**21 Claims, 7 Drawing Sheets**



U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 4,655,771 | A | | 4/1987 | Wallsten |
| 4,872,867 | A | | 10/1989 | Joh et al. |
| 4,886,062 | A | | 12/1989 | Wiktor |
| 4,916,193 | A | | 4/1990 | Tang et al. |
| 4,954,126 | A | | 9/1990 | Wallsten |
| 4,994,071 | A | | 2/1991 | McGregor |
| 5,061,275 | A | | 10/1991 | Wallsten et al. |
| 5,064,435 | A | * | 11/1991 | Porter ..... 623/12 |
| 5,092,877 | A | | 3/1992 | Pinchuk |
| 5,163,952 | A | | 11/1992 | Froix |
| 5,180,366 | A | | 1/1993 | Woods |
| 5,182,317 | A | | 1/1993 | Winters et al. |
| 5,185,408 | A | | 2/1993 | Tang et al. |
| 5,226,913 | A | | 7/1993 | Pinchuk |
| 5,258,020 | A | | 11/1993 | Froix |
| 5,262,451 | A | | 11/1993 | Winters et al. |
| 5,292,802 | A | | 3/1994 | Rhee et al. |
| 5,304,121 | A | | 4/1994 | Sahatjian |
| 5,308,889 | A | | 5/1994 | Rhee et al. |
| 5,338,770 | A | | 8/1994 | Winters et al. |
| 5,342,348 | A | | 8/1994 | Kaplan |
| 5,356,433 | A | | 10/1994 | Rowland et al. |
| 5,380,299 | A | | 1/1995 | Fearnot et al. |
| 5,415,619 | A | * | 5/1995 | Lee et al. ..... 600/36 |
| 5,419,760 | A | | 5/1995 | Narciso, Jr. |
| 5,429,618 | A | | 7/1995 | Keogh |
| 5,447,724 | A | | 9/1995 | Helmus et al. |
| 5,449,382 | A | | 9/1995 | Dayton |
| 5,464,650 | A | | 11/1995 | Berg et al. |
| 5,486,357 | A | * | 1/1996 | Narayanan ..... 424/78.17 |
| 5,545,208 | A | | 8/1996 | Wolff et al. |
| 5,578,075 | A | | 11/1996 | Dayton |
| 5,605,696 | A | * | 2/1997 | Eury et al. ..... 424/423 |
| 5,624,411 | A | * | 4/1997 | Tuch ..... 604/265 |
| 5,643,580 | A | * | 7/1997 | Subramaniam ..... 424/400 |
| 5,662,712 | A | * | 9/1997 | Pathak et al. ..... 623/12 |
| 5,688,855 | A | * | 11/1997 | Stoy et al. ..... 524/505 |
| 5,697,967 | A | * | 12/1997 | Dinh et al. ..... 623/1 |
| 5,700,559 | A | * | 12/1997 | Sheu et al. ..... 428/319.7 |
| 5,716,981 | A | | 2/1998 | Hunter et al. |
| 5,735,897 | A | * | 4/1998 | Buirge ..... 623/11 |
| 6,096,070 | A | | 8/2000 | Ragheb et al. |

OTHER PUBLICATIONS

Bergstrom, Reduction of fibrinogen adsorption on PEG–coated polystyrene surfaces, 1992, p. 779–790, Baxter Healthcare Corp. Duraflo Biocompatible Treatment.

Michael N. Helmus, "Medical Device Design—A Systems Approach: Central Venous Catheters", (1990).

Polysciences Inc., TDMAC–Heparin Coatings, Nov. 1988, Data Sheet #172.

Barbucci, et al., Coating of Commercially available materials with a new heparinizable material, 1991, pp. 1259–1274.

Michael N. Helmus, Grant Application–Ionic–Hydrophilic Density: Platelet/Monocyte Adherence 12/81 12/84, pp. 13, 14, 26–31.

Dennis E. Chenoweth, Complement Activation in Extracorporeal Circuits, pp. 306–329.

Jeffrey A. Hubbell, Ph.D., JuI.–Sep. 1993 Pharmacologic Modification of Materials, 1215–1275.

Glenn P. Gradlee, MD, Heparin–Coated Cardiopulmonary Bypass Circuits, Journal of Cardiothoracic and Vascular Anesthesia, vol. 8, No. 2, Apr. 1994, pp. 213–222.

K. Isihara, H. Hanyuda, and N. Nakabayashi, Synthesis of Phospholipid polymers having a urethane bond . . . , Biomaterials, 1995, pp. 873–879.

J. Sanchez, G. Elgue, J. Riesenfeld and P. Olsson, Control of Contact activiation on end–point immobilized heparin, The role of antithrombin and the specific antithrombin–binding sequence, 1995, pp. 655–661, Journal of Biomedical Materials Research.

Cardiology Conference European Society of Cardiology Conference Clinica, Sep. 4, 1995, pp. 24–26.

Mansoor Amjii and Kinam Park, "Surface Modification of Polymeric Biomaterials with Poly(Ehtylene Oxide), Albumin, and Heparin For Reduced Thrombogenicity", Purdue University, School of Pharmacy, West Lafayette, IN, 47907.

* cited by examiner

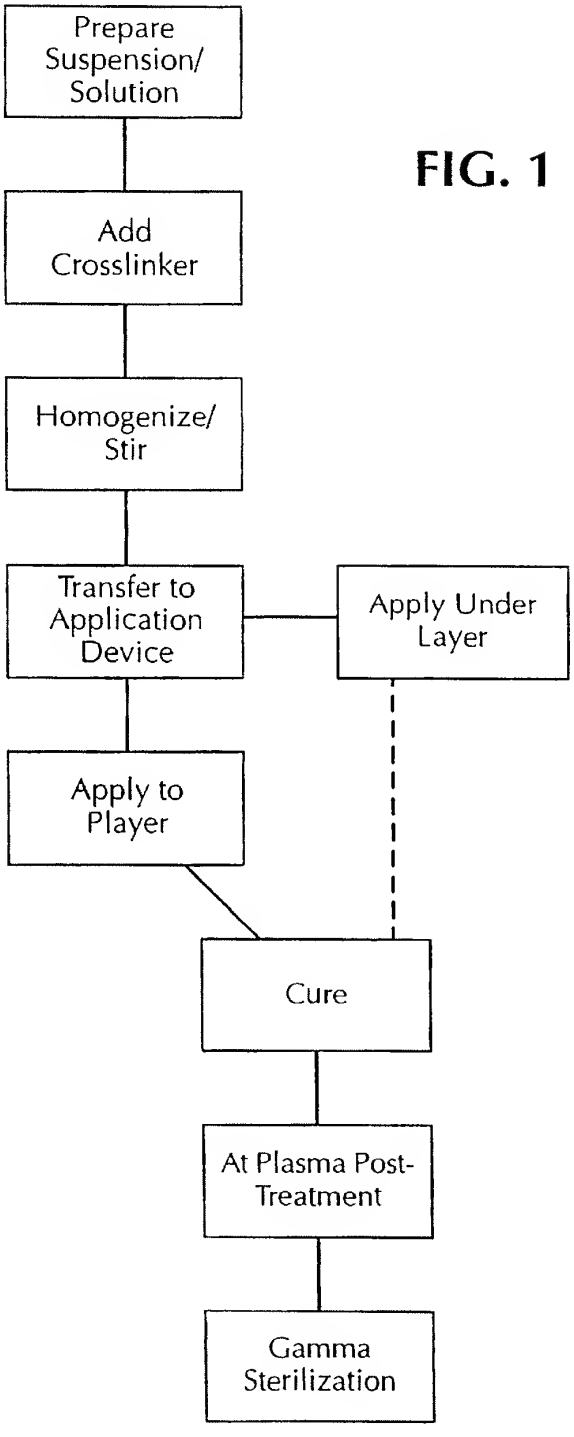

Prepare Suspension/ Solution
Add Crosslinker
Homogenize/ Stir
Transfer to Application Device
Apply Under Layer
Apply to Player
Cure
At Plasma Post-Treatment
Gamma Sterilization

FIG. 1

FIG. 2

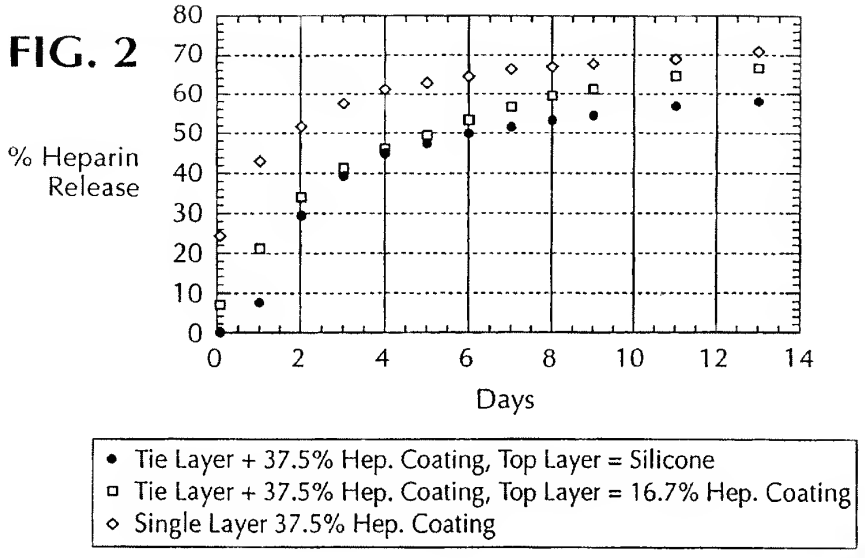

% Heparin Release
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
Days
• Tie Layer + 37.5% Hep. Coating, Top Layer = Silicone
▫ Tie Layer + 37.5% Hep. Coating, Top Layer = 16.7% Hep. Coating
◇ Single Layer 37.5% Hep. Coating

FIG. 3

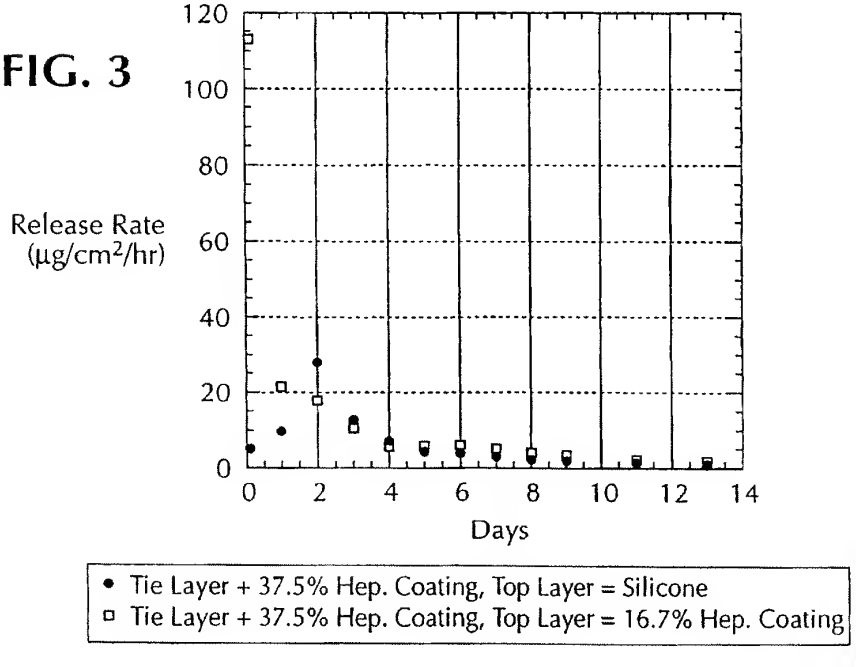

Release Rate (µg/cm²/hr)
120
100
80
60
40
20
0
0
2
4
6
8
10
12
14
Days
• Tie Layer + 37.5% Hep. Coating, Top Layer = Silicone
▫ Tie Layer + 37.5% Hep. Coating, Top Layer = 16.7% Hep. Coating

FIG. 4

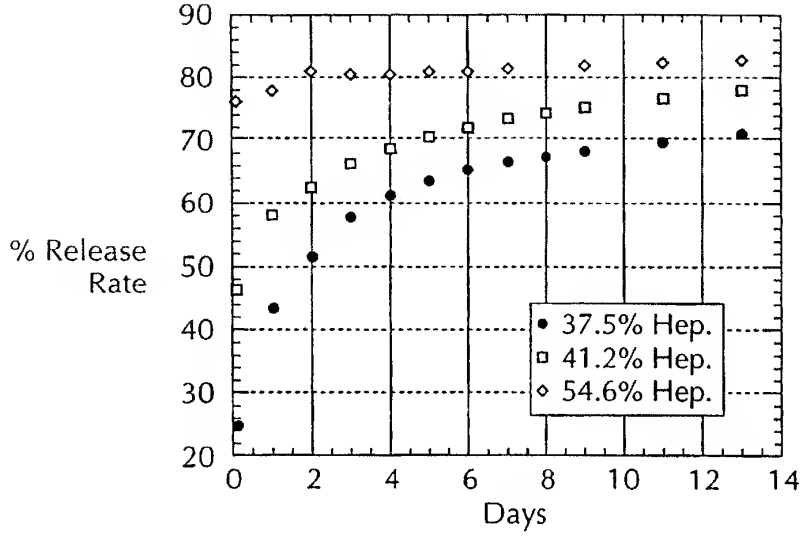

% Release Rate
90
80
70
60
50
40
30
20
0
2
4
6
8
10
12
14
Days
37.5% Hep.
41.2% Hep.
54.6% Hep.

FIG. 5

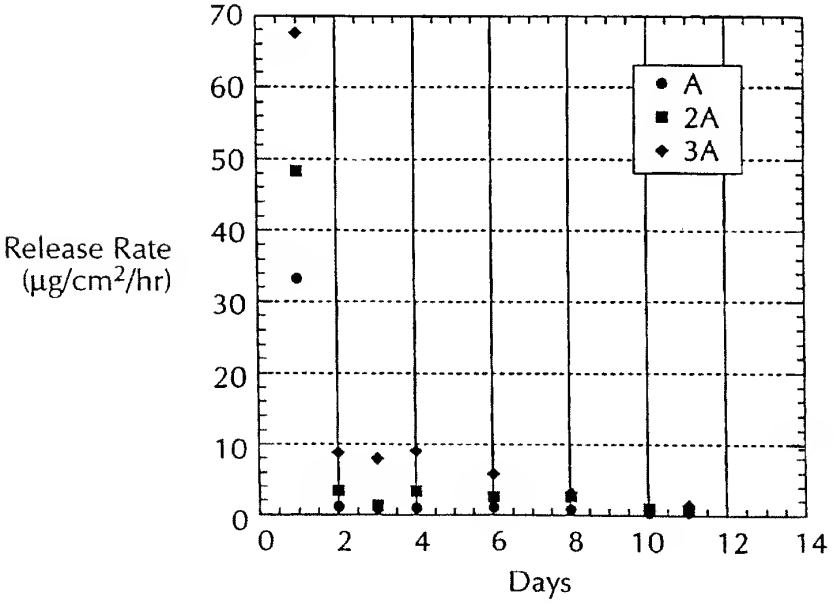
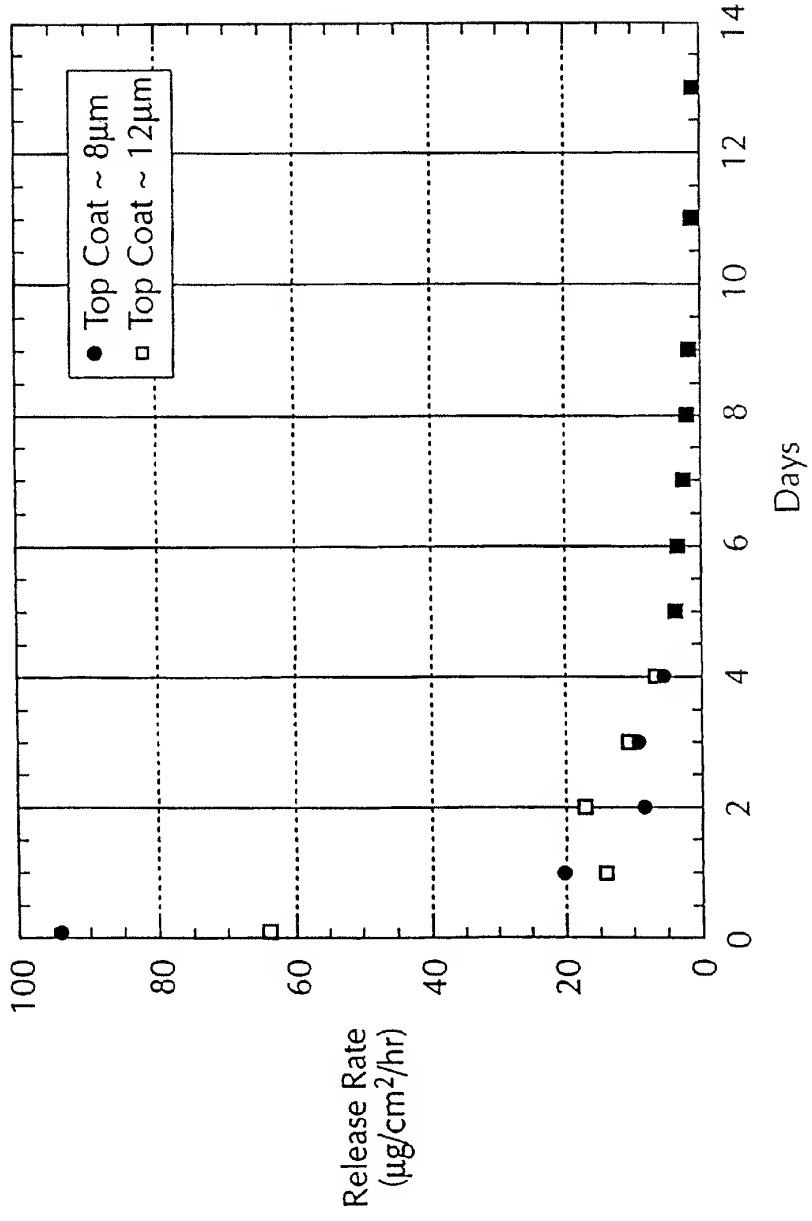

Release Rate (μg/cm²/hr)
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
Days
A
2A
3A

FIG. 6


Top Coat ~ 8µm
Top Coat ~ 12µm
Release Rate (µg/cm²/hr)
100
80
60
40
20
0
0
2
4
6
8
10
12
14
Days

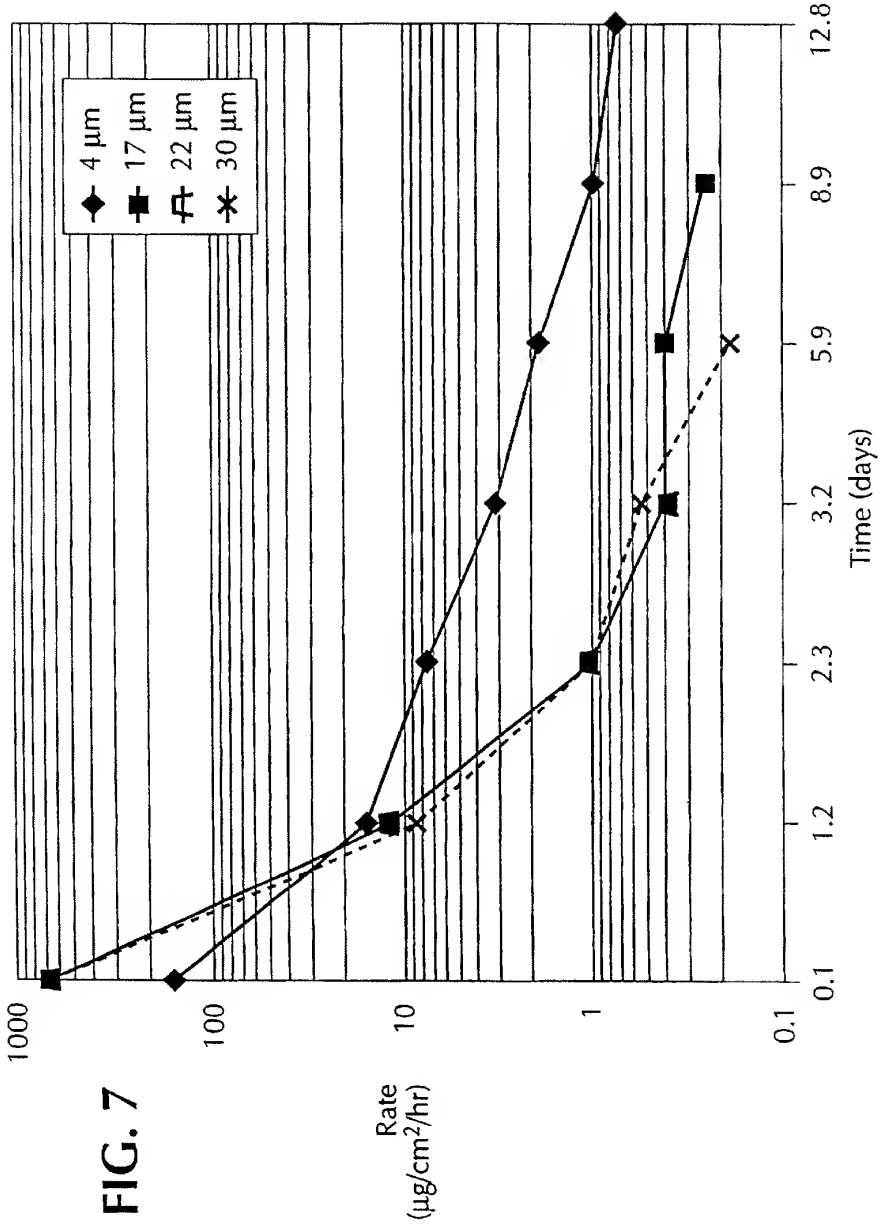

4 µm
17 µm
22 µm
30 µm
1000
100
10
1
0.1
Rate (µg/cm²/hr)
0.1
1.2
2.3
3.2
5.9
8.9
12.8
Time (days)

FIG. 7

FIG. 8

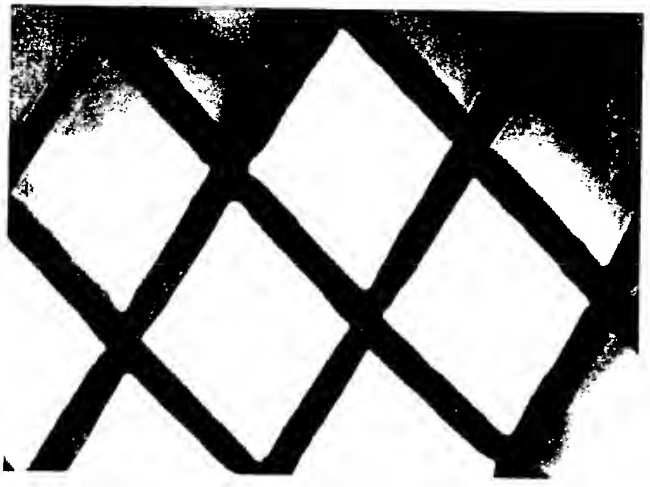


FIG. 9

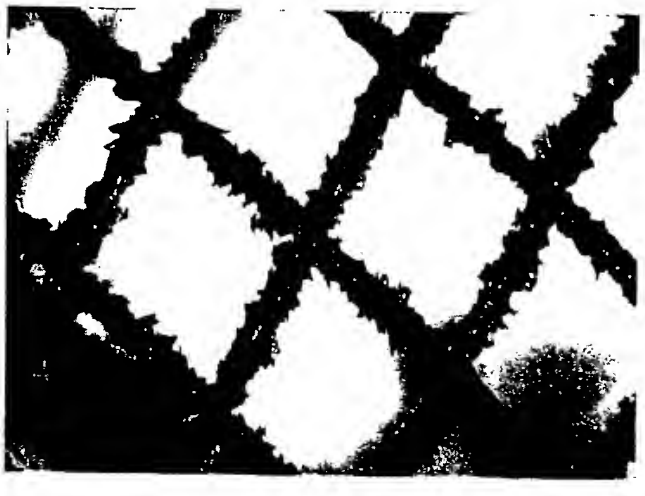
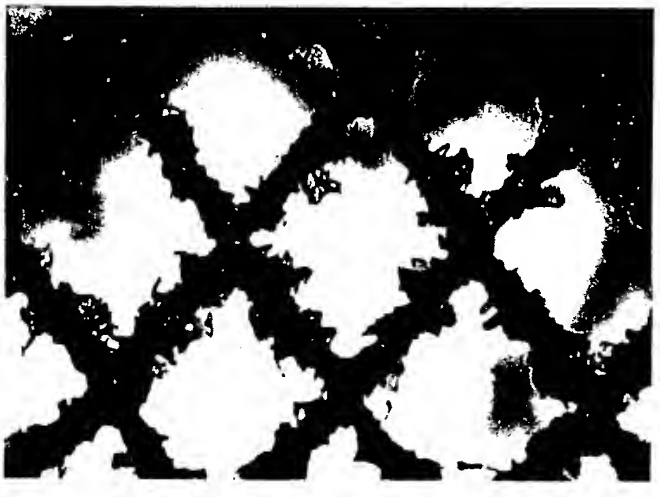


FIG. 10

FIG. 11



# DRUG RELEASE STENT COATING

## CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is a divisional of application Ser. No. 08/663,490 filed Jun. 13, 1996 now U.S. Pat. No. 5,887,313 which is a Continuation-In-Part of copending application Ser. No. 08/526,273, filed Sep. 11, 1995, and a Continuation-In-Part of copending application Ser. No. 08/424,884, filed Apr. 19, 1995, all portions of the parent applications not contained in this application being deemed incorporated by reference for any purpose. Cross-reference is also made to application Ser. No. 08/663,518, entitled "DRUG RELEASE STENT COATING AND PROCESS", filed of even date and of common inventorship and assignee, that is also a Continuation-In-Part of both above-referenced patent applications. Any portion of that application that is not contained herein is also deemed to be incorporated by reference for any purpose.

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to therapeutic expandable stent prosthesis for implantation in body lumens, e.g., vascular implantation and, more particularly, to a process for providing biostable elastomeric coatings on such stents which incorporate biologically active species having controlled release characteristics directly in the coating structure.

2. Related Art

In surgical or other related invasive medicinal procedures, the insertion and expansion of stent devices in blood vessels, urinary tracts or other difficult to access places for the purpose of preventing restenosis, providing vessel or lumen wall support or reinforcement and for other therapeutic or restorative functions has become a common form of long-term treatment. Typically, such prosthesis are applied to a location of interest utilizing a vascular catheter, or similar transluminal device, to carry the stent to the location of interest where it is thereafter released to expand or be expanded in situ. These devices are generally designed as permanent implants which may become incorporated in the vascular or other tissue which they contact at implantation.

One type of self-expanding stent has a flexible tubular body formed of several individual flexible thread elements each of which extends in a helix configuration with the centerline of the body serving as a common axis. The elements are wound in a common direction, but are displaced axially relative to each other and meet, under crossing a like number of elements also so axially displaced, but having the opposite direction of winding. This configuration provides a resilient braided tubular structure which assumes stable dimensions upon relaxation. Axial tension produces elongation and corresponding diameter contraction that allows the stent to be mounted on a catheter device and conveyed through the vascular system as a narrow elongated device. Once tension is relaxed in situ, the device at least substantially reverts to its original shape. Prosthesis of the class including a braided flexible tubular body are illustrated and described in U.S. Pat. Nos. 4,655,771 and 4,954,126 to Wallsten and U.S. Pat. No. 5,061,275 to Wallsten et al.

Implanted stents have also been used to carry medicinal agents, such as thrombolytic agents. U.S. Pat. No. 5,163,952 to Froix discloses a thermal memoried expanding plastic stent device which can be formulated to carry a medicinal agent by utilizing the material of the stent itself as an inert polymeric drug carrier. Pinchuk, in U.S. Pat. No. 5,092,877, discloses a stent of a polymeric material which may be employed with a coating associated with the delivery of drugs. Other patents which are directed to devices of the class utilizing bio-degradable or bio-sorbable polymers include Tang et al, U.S. Pat. No. 4,916,193, and MacGregor, U.S. Pat. No. 4,994,071. Sahatjian in U.S. Pat. No. 5,304,121, discloses a coating applied to a stent consisting of a hydrogel polymer and a preselected drug; possible drugs include cell growth inhibitors and heparin. A further method of making a coated intravascular stent carrying a therapeutic material in which a polymer coating is dissolved in a solvent and the therapeutic material dispersed in the solvent and the solvent thereafter evaporated is described in Berg et al, U.S. Pat. No. 5,464,650, issued Nov. 5, 1995 and corresponding to European patent application 0 623 354 A1 published Nov. 9, 1994.

An article by Michael N. Helmus (a co-inventor of the present invention) entitled "Medical Device Design—A Systems Approach: Central Venous Catheters", 22nd International Society for the Advancement of Material and Process Engineering Technical Conference (1990) relates to polymer/drug/membrane systems for releasing heparin. Those polymer/ drug/membrane systems require two distinct layers to function.

The above cross-referenced grandparent application supplies an approach that provides long-term drug release, i.e., over a period of days or even months, incorporated in a controlled-release system. The parent application and present invention provide a process for coating such stents including techniques that enable the initial burst effect of drug elation to be controlled and the drug release kinetic profile associated with long-term therapeutic effect to be modified.

Metal stents of like thickness and weave generally have better mechanical properties than polymeric stents. Metallic vascular stents braided of even relatively fine metal filament can provide a large amount of strength to resist inwardly directed circumferential pressure in blood vessels. In order for a polymer material to provide comparable strength characteristics, a much thicker-walled structure or heavier, denser filament weave is required. This, in turn, reduces the cross-sectional area available for flow through the stent and/or reduces the relative amount of open space available in the structure. In addition, when applicable, it is usually more difficult to load and deliver polymeric stents using vascular catheter delivery systems.

It will be noted, however, that while certain types of stents such as braided metal stents may be superior to others for some applications, the process of the present invention is not limited in that respect and may be used to coat a wide variety of devices. The present invention also applies, for example, to the class of stents that are not self-expanding including those which can be expanded, for instance, with a balloon. Polymeric stents, of all kinds can be coated using the process. Thus, regardless of particular detailed embodiments the use of the invention is not considered or intended to be limited with respect either to stent design or materials of construction. Further, the present invention may be utilized with other types of implant prostheses.

Accordingly, it is a primary object of the present invention to provide a coating process for coating a stent to be used as a deployed stent prosthesis, the coating being capable of long-term delivery of biologically active materials.

Another object of the invention is to provide a process for coating a stent prosthesis using a biostable hydrophobic

elastomer in which biologically active species are incorporated within a cured coating.

Still another object of the present invention is to provide a multi-layer coating in which the percentage of active material can vary from layer to layer.

A further object of the present invention is to control or modify aspects of the timed or time variable drug delivery from a stent coating by controlling average particle size in the biologically active species.

Other objects and advantages of the present invention will become apparent to those skilled in the art upon familiarization with the specification and appended claims.

## SUMMARY OF THE INVENTION

The present invention provides processes for producing a relatively thin layer of biostable elastomeric material in which an amount of biologically active material is dispersed as a coating on the surfaces of a deployable stent prosthesis. The preferred stent to be coated is a self-expanding, open-ended tubular stent prosthesis. Although other materials, including polymer materials, can be used, in the preferred embodiment, the tubular body is formed of an open braid of fine single or polyfilament metal wire which flexes without collapsing and readily axially deforms to an elongate shape for transluminal insertion via a vascular catheter. The stent resiliently attempts to resume predetermined stable dimensions upon relaxation in situ.

The coating is preferably applied as a mixture, solution or suspension of polymeric material and finely divided biologically active species dispersed in an organic vehicle or a solution or partial solution of such species in a solvent or vehicle for the polymer and/or biologically active species. For the purpose of this application, the term "finely divided" means any type or size of included material from dissolved molecules through suspensions, colloids and particulate mixtures. The active material is dispersed in a carrier material which may be the polymer, a solvent, or both. The coating is preferably applied as a plurality of relatively thin layers sequentially applied in relatively rapid sequence and is preferably applied with the stent in a radially expanded state. In some applications the coating may further be characterized as a composite initial tie coat or undercoat and a composite topcoat. The coating thickness ratio of the topcoat to the undercoat may vary with the desired effect and/or the elution system. Typically these are of different formulations.

The coating may be applied by dipping or spraying using evaporative solvent materials of relatively high vapor pressure to produce the desired viscosity and quickly establish coating layer thicknesses. The preferred process is predicated on reciprocally spray coating a rotating radially expanded stent employing an air brush device. The coating process enables the material to adherently conform to and cover the entire surface of the filaments of the open structure of the stent but in a manner such that the open lattice nature of the structure of the braid or other pattern is preserved in the coated device.

The coating is exposed to room temperature ventilation for a predetermined time (possibly one hour or more) for solvent vehicle evaporation. Thereafter the polymeric precuser material is cured at room temperature or elevated temperatures or the solvent evaporated away from the dissolved polymer as the case may be. Curing is defined as the process of converting the elastomeric or polymeric material into the finished or useful state by the application of heat and/or chemical agents which include physical-chemical charges. Where, for example, polyurethane thermoplastic elastomers are used, solvent evaporation can occur at room temperature rendering the polymeric material useful for controlled drug release without further curing. Non-limiting examples of curing according to this definition include the application of heat and/or chemical agents and the evaporation of solvent which may induce physical and/or chemical changes.

The ventilation time and temperature for cure are determined by the particular polymer involved and particular drugs used. For example, silicone or polysiloxane materials (such as polydimethylsiloxane) have been used successfully. These materials are applied as pre-polymer in the coating composition and must thereafter be cured. The preferred species have a relatively low cure temperatures and are known as a room temperature vulcanizable (RTV) materials. Some polydimethylsiloxane materials can be cured, for example, by exposure to air at about 90° C. for a period of time such as 16 hours. A curing step may be implemented both after application of a certain number of lower undercoat layers and the topcoat layers or a single curing step used after coating is completed.

The coated stents may thereafter be subjected to a post-cure sterilization process which includes an inert gas plasma treatment, and then exposure to gamma radiation, electron beam, ethylene oxide (ETO) or steam sterilization may also be employed.

In the plasma treatment, unconstrained coated stents are placed in a reactor chamber and the system is purged with nitrogen and a vacuum applied to about 20–50 mTorr. Thereafter, inert gas (argon, helium or mixture of them) is admitted to the reaction chamber for the plasma treatment. A highly preferred method of operation consists of using argon gas, operating at a power range from 200 to 400 watts, a flow rate of 150–650 standard ml per minute, which is equivalent to about 100–450 mTorr, and an exposure time from 30 seconds to about 5 minutes. The stents can be removed immediately after the plasma treatment or remain in the argon atmosphere for an additional period of time, typically five minutes.

After the argon plasma pretreatment, the coated and cured stents are subjected to gamma radiation sterilization nominally at 2.5–3.5 Mrad. The stents enjoy full resiliency after radiation whether exposed in a constrained or non-constrained status. It has been found that constrained stents subjected to gamma sterilization without utilizing the argon plasma pretreatment lose resiliency and do not recover at a sufficient or appropriate rate.

The elastomeric material that forms a major constituent of the stent coating should possess certain properties. It is preferably a suitable hydrophobic biostable elastomeric material which does not degrade and which minimizes tissue rejection and tissue inflammation and one which will undergo encapsulation by tissue adjacent to the stent implantation site. Polymers suitable for such coatings include silicones (e.g., polysiloxanes and substituted polysiloxanes), polyurethanes (including polycarbonate urethanes), thermoplastic elastomers in general, ethylene vinyl acetate copolymers, polyolefin elastomers, EPDM ethylene-propylene terpolymer rubbers and polyamide elastomers. The above-referenced materials are considered hydrophobic with respect to the contemplated environment of the invention.

Agents suitable for incorporation include antithrobotics, anticoagulants, antiplatelet agents, thrombolytics, antiproliferatives, antinflammatories, agents that inhibit

hyperplasia and in particular restenosis, smooth muscle cell inhibitors, antibiotics growth factors, growth factor inhibitors, cell adhesion inhibitors, cell adhesion promoters and drugs that may enhance the formation of healthy neointimal tissue, including endothelial cell regeneration. The positive action may come from inhibitiug particular cells (e.g., smooth muscle cells) or tissue formation (e.g., fibromuscular tissue) while encouraging different cell migration (e.g., endothelium) and tissue formation (neointimal tissue).

The preferred materials for fabricating the braided stent include stainless steel, tantalum, titanium alloys including nitinol (a nickel titanium, thermomemoried alloy material), and certain cobalt alloys including cobalt-chromium-nickel alloys such as ELGILOY® and PHYNOX®. Further details concerning the fabrication and details of other aspects of the stents themselves, may be gleaned from the above referenced U.S. Pat. Nos. 4,655,771 and 4,954,126 to Wallsten and 5,061,275 to Wallsten et al. To the extent additional information contained in the above-referenced patents is necessary for an understanding of the present invention, they are deemed incorporated by reference herein.

Various combinations of polymer coating materials can be coordinated with biologically active species of interest to produce desired effects when coated on stents to be implanted in accordance with the invention. Loadings of therapeutic material may vary. The mechanism of incorporation of the biologically active species into the surface coating, and egress mechanism depend both on the nature of the surface coating polymer and the material to be incorporated. The mechanism of release also depends on the mode of incorporation. The material may elute via interparticle paths or be administered via transport or diffusion through the encapsulating material itself.

For the purposes of this specification, "elution" is defined as any process of release that involves extraction or release by direct contact of the material with bodily fluids through the interparticle paths connected with the exterior of the coating. "Transport" or "diffusion" are defined to include a mechanism of release in which a material released traverses through another material.

The desired release rate profile can be tailored by varying the coating thickness, the radial distribution (layer to layer) of bioactive materials, the mixing method, the amount of bioactive material, the combination of different matrix polymer materials at different layers, and the crosslink density of the polymeric material. The crosslink density is related to the amount of crosslinking which takes place and also the relative tightness of the matrix created by the particular crosslinking agent used. This, during the curing process, determines the amount of crosslinking and so the crosslink density of the polymer material. For bioactive materials released from the crosslinked matrix, such as heparin, a crosslink structure of greater density will increase release time and reduce burst effect.

Additionally, with eluting materials such as heparin, release kinetics, particularly initial drug release rate, can be affected by varying the average dispersed particle size. The observed initial release rate or burst effect may be substantially reduced by using smaller particles, particularly if the particle size is controlled to be less than about 15 microns and the effect is even more significant in the particle size range of $\leqq 10$ microns, especially when the coating thickness is not more than about 50 $\mu$m and drug loading is about 25–45 weight percent.

It will also be appreciated that an unmedicated silicone thin top layer provides an advantage over drug containing top coat. Its surface has a limited porosity and is generally smooth, which may be less thrombogeneous and may reduce the chance to develop calcification, which occurs most often on the porous surface.

## BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, wherein like numerals designate like parts throughout the same:

FIG. **1** is a schematic flow diagram illustrating the steps of the process of the invention;

FIG. **2** represents a release profile for a multi-layer system showing the percentage of heparin released over a two-week period;

FIG. **3** represents a release profile for a multi-layer system showing the relative release rate of heparin over a two-week period;

FIG. **4** illustrates a profile of release kinetics for different drug loadings at similar coating thicknesses illustrating the release of heparin over a two-week period;

FIG. **5** illustrates drug elution kinetics at a given loading of heparin over a two-week period at different coating thicknesses;

FIG. **6** illustrates the release kinetics in a coating having a given tie-layer thickness for different top coat thicknesses in which the percentage heparin in the tie coat and top coats are kept constant;

FIG. **7** illustrates the release kinetics of several coatings having an average coating thickness of 25 microns and a heparin loading of 37.5% but using four different average particle sizes;

FIGS. **8–11** are photomicrographs of coated stent fragments for the coatings of FIG. **7** having a corresponding average particle size of 4 microns, 17 microns, 22 microns and 30 microns, respectively.

## DETAILED DESCRIPTION

According to the present invention, the stent coatings incorporating biologically active materials for timed delivery in situ in a body lumen of interest are preferably sprayed in many thin layers from prepared coating solutions or suspensions. The steps of the process are illustrated generally in FIG. **1**. The coating solutions or suspensions are prepared at **10** as will be described later. The desired amount of crosslinking agent is added to the suspension/solution as at **12** and material is then agitated or stirred to produce a homogenous coating composition at **14** which is thereafter transferred to an application container or device which may be a container for spray painting at **16**. Typical exemplary preparations of coating solutions that were used for heparin and dexamethasone appear next.

### General Preparation of Heparin Coating Composition

Silicone was obtained as a polymer precursor in solvent (xylene) mixture. For example, a 35% solid silicone weight content in xylene was procured from Applied Silicone, Part #40,000. First, the silicone-xylene mixture was weighed. The solid silicone content was determined according to the vendor's analysis. Precalculated amounts of finely divided heparin (2–6 microns) were added into the silicone, then tetrahydrofuron (THF) HPCL grade (Aldrich or EM) was added. For a 37.5% heparin coating, for example: $W_{silicone}$=5 g; solid percent=35%; $W_{hep}$=5×0.35×0.375/(0.625)=1.05 g. The amount of THF needed (44 ml) in the

coating solution was calculated by using the equation $W_{silicone\ solid}/V_{THF}$=0.04 for a 37.5% heparin coating solution). Finally, the manufacturer crosslinker solution was added by using Pasteur P-pipet. The amount of crosslinker added was formed to effect the release rate profile. Typically, five drops of crosslinker solution were added for each five grams of silicone-xylene mixture. The crosslinker may be any suitable and compatible agent including platinum and peroxide based materials. The solution was stirred by using the stirring rod until the suspension was homogenous and milk-like. The coating solution was then transferred into a paint jar in condition for application by air brush.

General Preparation of Dexamethasone Coating Composition

Silicone (35% solution as above) was weighed into a beaker on a Metler balance. The weight of dexamethasone free alcohol or acetate form was calculated by silicone weight multiplied by 0.35 and the desired percentage of dexamethasone (1 to 40%) and the required amount was then weighed. Example: $W_{silicone}$=5 g; for a 10% dexamethasone coating, $W_{dex}$=5×0.35×0.1/0.9=0.194 g and THF needed in the coating solution calculated. $W_{silicone\ solid}/V_{THF}$=0.06 for a 10% dexamethasone coating solution. Example: $W_{silicone}$=5 g; $V_{THF}$=5×0.35/0.06=29 ml. The dexamethasone was weighed in a beaker on an analytical balance and half the total amount of THF was added. The solution was stirred well to ensure full dissolution of the dexamethasone. The stirred DEX-THF solution was then transferred to the silicone container. The beaker was washed with the remaining THF and this was transferred to the silicone container. The crosslinker was added by using a Pasteur pipet. Typically, five drops of crosslinker were used for five grams of silicone.

The application of the coating material to the stent was quite similar for all of the materials and the same for the heparin and dexamethasone suspensions prepared as in the above Examples. The suspension to be applied was transferred to an application device, typically a paint jar attached to an air brush, such as a Badger Model 150, supplied with a source of pressurized air through a regulator (Norgren, 0–160 psi). Once the brush hose was attached to the source of compressed air downstream of the regulator, the air was applied. The pressure was adjusted to approximately 15–25 psi and the nozzle condition checked by depressing the trigger.

Any appropriate method can be used to secure the stent for spraying and rotating fixtures were utilized successfully in the laboratory. Both ends of the relaxed stent were fastened to the fixture by two resilient retainers, commonly alligator clips, with the distance between the clips adjusted so that the stent remained in a relaxed, unstretched condition. The rotor was then energized and the spin speed adjusted to the desired coating speed, nominally about 40 rpm.

With the stent rotating in a substantially horizontal plane, the spray nozzle was adjusted so that the distance from the nozzle to the stent was about 2–4 inches and the composition was sprayed substantially horizontally with the brush being directed along the stent from the distal end of the stent to the proximal end and then from the proximal end to the distal end in a sweeping motion at a speed such that one spray cycle occurred in about three stent rotations. Typically a pause of less than one minute, normally about one-half minute, elapsed between layers. Of course, the number of coating layers did and will vary with the particular application. For example, for a coating level of 3–4 mg of heparin per $cm^2$ of projected area, 20 cycles of coating application are required and about 30 ml of solution will be consumed for a 3.5 mm diameter by 14.5 cm long stent.

The rotation speed of the motor, of course, can be adjusted as can the viscosity of the composition and the flow rate of the spray nozzle as desired to modify the layered structure. Generally, with the above mixes, the best results have been obtained at rotational speeds in the range of 30–50 rpm and with a spray nozzle flow rate in the range of 4–10 ml of coating composition per minute, depending on the stent size. It is contemplated that a more sophisticated, computer-controlled coating apparatus will successfully automate the process demonstrated as feasible in the laboratory.

Several applied layers make up what is called the tie layer as at **18** and thereafter additional upper layers, which may be of a different composition with respect to bioactive material, the matrix polymeric materials and crosslinking agent, for example, are applied as the top layer as at **20**. The application of the top layer follows the same coating procedure as the tie layer with the number and thickness of layers being optional. Of course, the thickness of any layer can be adjusted by modifying the speed of rotation of the stent and the spraying conditions. Generally, the total coating thickness is controlled by the number of spraying cycles or thin coats which make up the total coat.

As shown at **22** in FIG. **1**, the coated stent is thereafter subjected to a curing step in which the pre-polymer and crosslinking agents cooperate to produce a cured polymer matrix containing the biologically active species. The curing process involves evaporation of the solvent xylene, THF, etc. and the curing and crosslinking of the polymer. Certain silicone materials can be cured at relatively low temperatures, (i.e. RT-50° C.) in what is known as a room temperature vulcanization (RTV) process. More typically, however, the curing process involves higher temperature curing materials and the coated stents are put into an oven at approximately 90° C. or higher for approximately **16** hours. The temperature may be raised to as high as 150° C. for dexamethasone containing coated stents. Of course, the time and temperature may vary with particular silicones, crosslinkers, and biologically active species.

Stents coated and cured in the manner described need to be sterilized prior to packaging for future implantation. For sterilization, gamma radiation is a preferred method particularly for heparin containing coatings; however, it has been found that stents coated and cured according to the process of the invention subjected to gamma sterilization may be too slow to recover their original posture when delivered to a vascular or other lumen site using a catheter unless a pretreatment step as at **24** is first applied to the coated, cured stent.

The pretreatment step involves an argon plasma treatment of the coated, cured stents in the unconstrained configuration. In accordance with this procedure, the stents are placed in a chamber of a plasma surface treatment system such as a Plasma Science 350 (Himont/Plasma Science, Foster City, Calif.). The system is equipped with a reactor chamber and RF solid-state generator operating at 13.56 mHz and from 0–500 watts power output and being equipped with a microprocessor controlled system and a complete vacuum pump package. The reaction chamber contains an unimpeded work volume of 16.75 inches (42.55 cm) by 13.5 inches (34.3 cm) by 17.5 inches (44.45 cm) in depth.

In the plasma process, unconstrained coated stents are placed in a reactor chamber and the system is purged with

nitrogen and a vacuum applied to 20–50 mTorr. Thereafter, inert gas (argon, helium or mixture of them) is admitted to the reaction chamber for the plasma treatment. A highly preferred method of operation consists of using argon gas, operating at a power range from 200 to 400 watts, a flow rate of 150–650 staudard ml per minute, which is equivalent to 100–450 mTorr, and an exposure time from 30 seconds to about 5 minutes. The stents can be removed immediately after the plasma treatment or remain in the argon atmosphere for an additional period of time, typically five minutes.

After this, as shown at **26**, the stents are exposed to gamma sterilization at 2.5–3.5 Mrad. The radiation may be carried out with the stent in either the radially non-constrained status—or in the radially constrained status.

With respect to the anticoagulant material heparin, the percentage in the tie layer is nominally from about 20–50% and that of the top layer from about 0–30% active material. The coating thickness ratio of the top layer to the tie layer varies from about 1:10 to 1:2 aud is preferably in the range of from about 1:6 to 1:3.

Suppressing the burst effect also enables a reduction in the drug loading or in other words, allows a reduction in the coating thickness, since the physician will give a bolus injection of antiplatelet/anticoagulation drugs to the patient during the stenting process. As a result, the drug imbedded in the stent can be fully used without waste. Tailoring the first day release, but maximizing second day and third day release at the thinnest possible coating configuration will reduce the acute or subcute thrombosis.

FIG. **4** depicts the general effect of drug loading for coatings of similar thickness. The initial elution rate increases with the drug loading as shown in FIG. **5**. The release rate also increases with the thickness of the coating at the same loading but tends to be inversely proportional to the thickness of the top layer as shown by the same drug loading and similar tie-coat thickness in FIG. **6**.

The effect of average particle size is depicted in the FIGS. **7–11** in which coating layers with an average coating thickness of about 25 microns ($\mu$m), prepared and sterilized as above, were provided with dispersed heparin particles (to 37.5% heparin) of several different average particle sizes. FIG. 7 shows plots of elution kinetics for four different sizes of embedded heparin particles. The release took place in phosphate buffer (pH 7.4) at 37° C. The release rate using smaller, particularly 4–6 $\mu$m average sized particles noticeably reduces the initial rate or burst effect and thereafter the elution rate decreases more slowly with time. Average particle sizes above about 15 $\mu$m result in initial release rates approaching bolus elution. This, of course, is less desirable, both from the standpoint of being an unnecessary initial excess and for prematurely depleting the coating of deserved drug material.

In addition, as shown in the photomicrographs of FIGS. **8–11**, as the average particle size increases, the morphology of the coating surface also changes. Coatings containing larger particles (FIGS. **9–11**) have very rough and irregular surface characteristics. These surface irregularities may be more thrombogenic or exhibit an increased tendency to cause embolization when the corresponding stent is implanted in a blood vessel.

Accordingly, it has been found that the average particle size should generally be controlled below about 15 $\mu$m to reduce the burst effect and preferably should be $\leqq$ about 10 $\mu$m for best results. The 4–6 $\mu$m size worked quite successfully in the laboratory. However, it should be noted that larger particle size can also be advantageously used, for instance, when the drug load is low, such as below 25 weight percent. Elution kinetics can be adjusted by a combination of changing the particle size and changing the load or concentration of the dispersed drug material.

What is apparent from the data gathered to date, however, is that the process of the present invention enables the drug elution kinetics to be modified to meet the needs of the particular stent application. In a similar manner, stent coatings can be prepared using a combination of two or more drugs and the drug release sequence and rate controlled. For example, antiproliferation drugs may be combined in the undercoat and anti-thrombotic drugs in the topcoat layer. In this manner, the anti-thrombotic drugs, for example, heparin, will elute first followed by antiproliferation drugs, e.g. dexamethasone, to better enable safe encapsulation of the implanted stent.

The heparin concentration measurement were made utilizing a standard curve prepared by complexing azure A dye with dilute solutions of heparin. Sixteen standards were used to compile the standard curve in a well-known manner.

For the elution test, the stents were immersed in a phosphate buffer solution at pH 7.4 in an incubator at approximately 37° C. Periodic samplings of the solution were processed to determine the amount of heparin eluted. After each sampling, each stent was placed in heparin-free buffer solution.

As stated above, while the allowable loading of the elastomeric material with heparin may vary, in the case of silicone materials heparin may exceed 60% of the total weight of the layer. However, the loading generally most advantageously used is in the range from about 10% to 45% of the total weight of the layer. In the case of dexamethasone, the loading may be as high as 50% or more of the total weight of the layer but is preferably in the range of about 0.4% to 45%.

It will be appreciated that the mechanism of incorporation of the biologically active species into a thin surface coating structure applicable to a metal stent is an important aspect of the present invention. The need for relatively thick-walled polymer elution stents or any membrane overlayers associated with many prior drug elution devices is obviated, as is the need for utilizing biodegradable or reabsorbable vehicles for carrying the biologically active species. The technique clearly enables long-term delivery and minimizes interference with the independent mechanical or therapeutic benefits of the stent itself.

Coating materials are designed with a particular coating technique, coating/drug combination and drug infusion mechanism in mind. Consideration of the particular form and mechanism of release of the biologically active species in the coating allow the technique to produce superior results. In this manner, delivery of the biologically active species from the coating structure can be tailored to accommodate a variety of applications.

Whereas the above examples depict-coatings having two different drug loadings or percentages of biologically active material to be released, this is by no means limiting with respect to the invention and it is contemplated that any number of layers and combinations of loadings can be employed to achieve a desired release profile. For example, gradual grading and change in the loading of the layers can be utilized in which, for example, higher loadings are used in the inner layers. Also layers can be used which have no drug loadings at all. For example, a pulsatile heparin release system may be achieved by a coating in which alternate layers containing heparin are sandwiched between unloaded

layers of silicone or other materials for a portion of the coating. In other words, the invention allows untold numbers of combinations which result in a great deal of flexibility with respect to controlling the release of biologically active materials with regard to an implanted stent. Each applied layer is typically from approximately 0.5 microns to 15 microns in thickness. The total number of sprayed layers, of course, can vary widely, from less than 10 to more than 50 layers; commonly, 20 to 40 layers are included. The total thickness of the coating can also vary widely, but can generally be from about 10 to 200 microns.

Whereas the polymer of the coating may be any compatible biostable elastomeric material capable of being adhered to the stent material as a thin layer, hydrophobic materials are preferred because it has been found that the release of the biologically active species can generally be more predictably controlled with such materials. Preferred materials include silicone rubber elastomers and biostable polyurethanes specifically.

This invention has been described herein in considerable detail in order to comply with the Patent Statutes and to provide those skilled in the art with the information needed to apply the novel principles and to construct and use embodiments of the example as required. However, it is to be understood that the invention can be carried out by specifically different devices and that various modifications can be accomplished without departing from the scope of the invention itself.

We claim:

**1**. A process for making an implantable medical prosthesis in which at least a portion of the prosthesis is covered with a coating, wherein the process comprises:

(a) applying a composition, comprising a polymeric material incorporating a biologically active material, to the portion of the prosthesis to form a coating thereon;

(b) curing the coating;

(c) exposing the portion of the prosthesis to an inert gas plasma treatment after the coating is cured; and

(d) sterilizing the portion of the prosthesis with gamma radiation.

**2**. The process of claim **1** wherein the inert gas is selected from the group consisting of argon, helium or mixtures thereof.

**3**. The process of claim **2** wherein the inert gas is argon.

**4**. The process of claim **1** wherein the portion of the prosthesis is exposed to the inert gas plasma treatment for about 30 seconds to about 5 minutes.

**5**. The process of claim **4** wherein the portion of the prosthesis is exposed to the inert gas for an additional period of time.

**6**. The process of claim **5** wherein the additional period of time is about 5 minutes.

**7**. The process of claim **1** wherein the gamma radiation is about 2.5 to about 3.5 Mrad.

**8**. The process of claim **1** wherein the coating is cured by a method selected from the group consisting of applying a heat source to the coating and applying a chemical agent to the coating.

**9**. The process of claim **1** wherein the biologically active material has an average particle size of equal to or less than about 15 $\mu$m.

**10**. The process of claim **9** wherein the biologically active material has an average particle size of equal to or less than about 10 $\mu$m.

**11**. The process of claim **9** wherein the coating reduces an initial burst release of the biologically active material upon implantation of the prosthesis as compared to a coating comprising the same biologically active material having an average particle size greater than about 15 $\mu$m.

**12**. The process of claim **1** wherein the composition comprises about 25–45 weight percent of the biologically active material.

**13**. The process of claim **1** wherein the biologically active material includes heparin.

**14**. The process of claim **1** wherein the polymeric material is a hydrophobic elastomeric material.

**15**. The process of claim **14** wherein the hydrophobic elastomeric material is selected from the group consisting of silicones, polyurethanes, polyamide elastomers, ethylene vinyl acetate copolymers, polyolefin elastomers, ethylene-propylene terpolymer rubbers and combinations thereof.

**16**. The process of claim **14** wherein the prosthesis is an expandable stent having a tubular metal body having open ends and a sidewall structure having openings therein and wherein the composition is applied to the stent in a manner such that the composition adheringly conforms to the sidewall structure to preserve the openings therein when the stent is expanded.

**17**. An implantable medical prosthesis prepared according to the process of claim **1**.

**18**. The process of claim **1** Wherein the prosthesis is an expandable stent.

**19**. The process of claim **18** wherein the expandable stent is self-expanding.

**20**. A process for making an expandable stent in which at least a portion of the stent is covered with a coating, wherein the process comprises:

(a) applying a composition, comprising a hydrophobic elastomeric material incorporating a biologically active material, to the portion of the stent to form a coating thereon;

(b) curing the coating;

(c) exposing the portion of the stent to an argon plasma treatment after the coating is cured; and

(d) sterilizing the portion of the stent with gamma radiation.

**21**. A process for making an expandable stent in which at least a portion of the stent is covered with a coating, wherein the process comprises:

(a) applying a composition, comprising a polymeric material incorporating a biologically active material, to the portion of the stent to form a coating thereon;

(b) curing the coating;

(c) exposing the portion of the stent to an argon plasma treatment for about 30 seconds to about 5 minutes after the coating is cured; and

(d) sterilizing the portion of the stent with gamma radiation of about 2.5 to about 3.4 Mrad.

* * * * *

EVIDENCE APPENDIX "C"

US006407009B1

(12) **United States Patent**
**You et al.**

(10) **Patent No.: US 6,407,009 B1**
(45) **Date of Patent: *Jun. 18, 2002**

(54) **METHODS OF MANUFACTURE OF UNIFORM SPIN-ON FILMS**

(75) Inventors: **Lu You**, Santa Clara; **Dawn Hopper**, San Jose; **Richard J. Huang**, Cupertino, all of CA (US)

(73) Assignee: **Advanced Micro Devices, Inc.**, Sunnyvale, CA (US)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **09/190,722**

(22) Filed: **Nov. 12, 1998**

(51) **Int. Cl.**[7] ..... **H01L 21/30**
(52) **U.S. Cl.** ..... **438/782**; 427/240
(58) **Field of Search** ..... 438/622, 623, 438/758, 759, 760, 761, 778, 780, 781, 782, 790; 427/240

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 3,980,042 | A | 9/1976 | Stut | 118/5 |
| 4,817,558 | A | 4/1989 | Itoh | 118/725 |
| 4,849,296 | A | 7/1989 | Haluska et al. | 428/457 |
| 4,996,080 | A | 2/1991 | Daraktchiev | 427/57 |
| 5,134,962 | A | 8/1992 | Amada et al. | 118/688 |
| 5,138,520 | A | 8/1992 | McMillan et al. | 361/311 |
| 5,587,330 | A | 12/1996 | Yamazaki | 437/41 |
| 5,602,060 | A | 2/1997 | Kobayashi et al. | 437/238 |
| 5,630,881 | A | 5/1997 | Ogure et al. | 118/730 |
| 5,646,071 | A | 7/1997 | Lin et al. | 485/228 |
| 5,648,282 | A | 7/1997 | Yoneda | 437/40 |
| 5,670,210 | A | 9/1997 | Mandal et al. | 427/240 |
| 5,707,900 | A | 1/1998 | Sano et al. | 438/509 |
| 5,773,082 | A * | 6/1998 | Ku et al. | 427/240 |
| 5,773,083 | A * | 6/1998 | Fischer et al. | 427/240 |
| 5,780,105 | A * | 7/1998 | Wang | 427/240 |
| 5,837,618 | A * | 11/1998 | Avanzino et al. | 438/778 |
| 5,840,821 | A | 11/1998 | Nokano et al. | 528/10 |
| 5,874,128 | A | 2/1999 | Kim | 427/240 |
| 5,883,001 | A | 3/1999 | Jin et al. | 438/624 |

(List continued on next page.)

OTHER PUBLICATIONS

Wang, "Spin-On Dielectric Films—A General Overview," Solid State and Integrated Circuit Technology, 1998, Proceedings, 1998 5th International Conference, IEEE/EE Electronic Library Online, Abstract, p. 961.

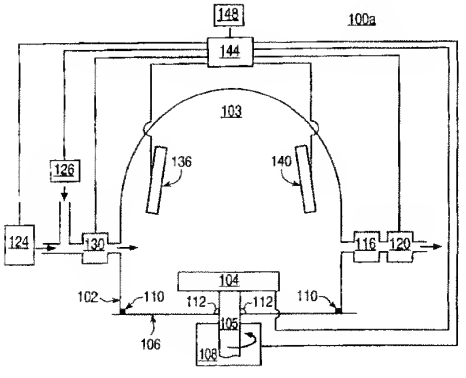
(List continued on next page.)

*Primary Examiner*—Savitri Mulpuri
(74) *Attorney, Agent, or Firm*—Fliesler, Dubb, Meyer & Lovejoy LLP

(57) **ABSTRACT**

This invention describes improved apparatus and methods for spin-on deposition of semiconductor thin films. The improved apparatus provides for controlled temperature, pressure and gas compositions within the deposition chamber. The improved methods comprise dispensing of solutions containing thin film precursor via a moveable dispensing device and the careful regulation of the pattern of deposition of the precursor solution onto the wafer. The invention also comprises the careful regulation of deposition variables including dispensation time, wafer rpm, stop time and rates of wafer rotation. In one embodiment, the precursor solution is dispensed from the outer edge of the wafer toward the center. In alternative embodiments, processors regulate the movement of the dispensing arm and the precursor pump to provide an evenly dispensed layer of precursor solution. The invention also describes improved methods for evaporating solvents and curing thin films. The methods of this invention enable the production of spin-on thin films, which have more even film thickness and uniformity. The semiconductor thin films produced by the methods of this invention are useful for the manufacture of semiconductor devices comprising interlevel dielectric materials.

**31 Claims, 13 Drawing Sheets**



U.S. PATENT DOCUMENTS

| | | | | | |
|---|---|---|---|---|---|
| 5,912,049 | A | * | 6/1999 | Shirley | 427/240 |
| 5,925,410 | A | | 7/1999 | Akram et al. | 427/240 |
| 5,939,130 | A | | 8/1999 | Shiraishi et al. | 427/9 |
| 5,942,035 | A | | 8/1999 | Hasebe et al. | 118/52 |
| 5,962,085 | A | | 10/1999 | Hayashi et al. | 427/585 |
| 5,981,359 | A | * | 11/1999 | Spikes et al. | 438/424 |
| 5,985,363 | A | | 11/1999 | Shiau et al. | 427/240 |
| 5,985,364 | A | | 11/1999 | Smith et al. | 427/240 |
| 5,989,632 | A | | 11/1999 | Sanada et al. | 427/240 |
| 5,989,945 | A | | 11/1999 | Yudasaka et al. | 438/149 |
| 6,004,622 | A | * | 12/1999 | Yeh et al. | 438/760 |
| 6,015,457 | A | | 1/2000 | Leung et al. | 106/287.16 |
| 6,017,806 | A | | 1/2000 | Harvey | 438/475 |
| 6,020,273 | A | * | 2/2000 | Cheng et al. | 438/782 |
| 6,048,804 | A | * | 4/2000 | Smith et al. | 438/790 |
| 6,056,998 | A | | 5/2000 | Fujimoto | 427/240 |
| 6,066,574 | A | * | 5/2000 | You et al. | 438/781 |
| 6,071,807 | A | * | 6/2000 | Watanabe et al. | 438/623 |
| 6,071,831 | A | * | 6/2000 | Chiang et al | 438/778 |
| 6,074,962 | A | * | 6/2000 | Sakamoto et al. | 438/790 |
| 6,099,646 | A | | 8/2000 | Yang et al. | 118/684 |
| 6,127,279 | A | | 10/2000 | Konuma | 438/745 |
| 6,139,639 | A | | 10/2000 | Kitamura et al. | 118/680 |

OTHER PUBLICATIONS

Wolf, Ph.D., et al., "Silicon Processing for the VLSI Era, vol. 1: Process Technology," *Lattice Press,* pp. 265–266, 430–434.

Jacobson, D., et al., "Recommendation for Priming a Filter in a Wafergard Gen–2 Pump," Microelectronics Division, Millipore Corporation, Oct. 12, 1994, pp. 1,3, and 5.

Bowers, William, et al., "Design, Performance Validation, and Reliability Testing of a New Photochemical Dispense Pump," Millipore Corporation and Silicon Valley Group, Inc.

"Wafergard® Gen–2 Photochemical Dispense System," Data Sheet, Millipore.

"Wafergard® Gen–2$^{Plus}$ Photochemical Dispense System," Data Sheet, Millipore.

Treichel, et al., "Low Dielectric Constant Materials for Interlayer Dielectric," Dumic Conference, Feb. 16–17, 1998, 1998 IMIC—333D/98/0201, pp. 1–10.

Giannelis, et al., "Spin–On Films Add New Dimensions to ULSI Circuits," *IEEE Circuits and Devices Magazine,* Nov. 1993, vol. 9, Issue 6, pp. 30–34.

* cited by examiner

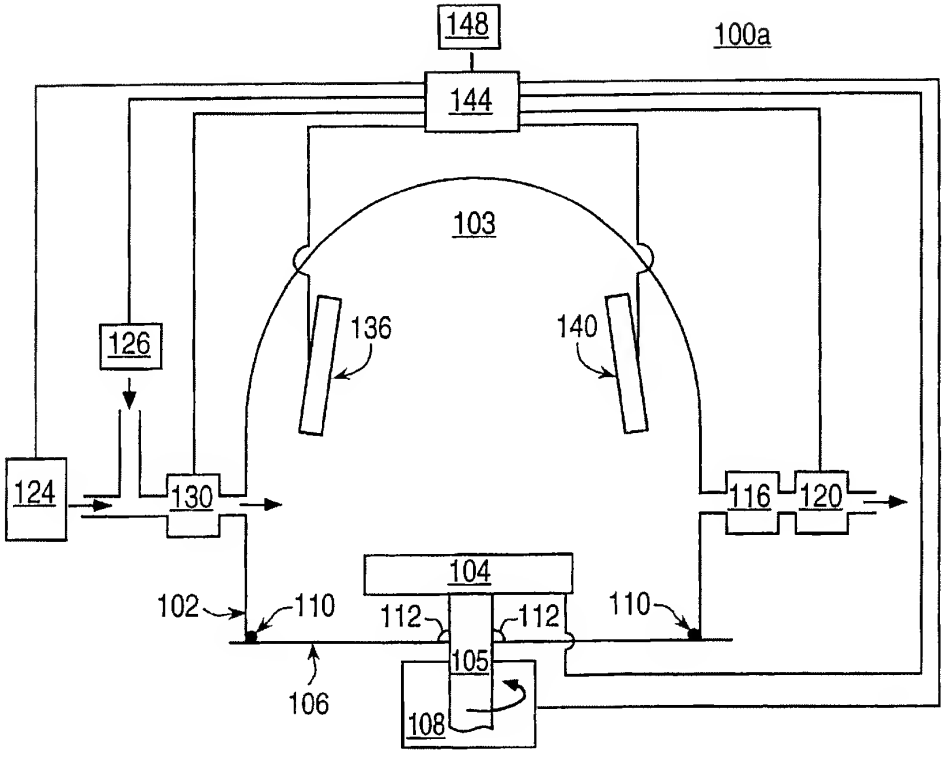

148
100a
144
103
126
136
140
124
130
116
120
104
102
110
112
112
110
105
106
108

FIG. 1a

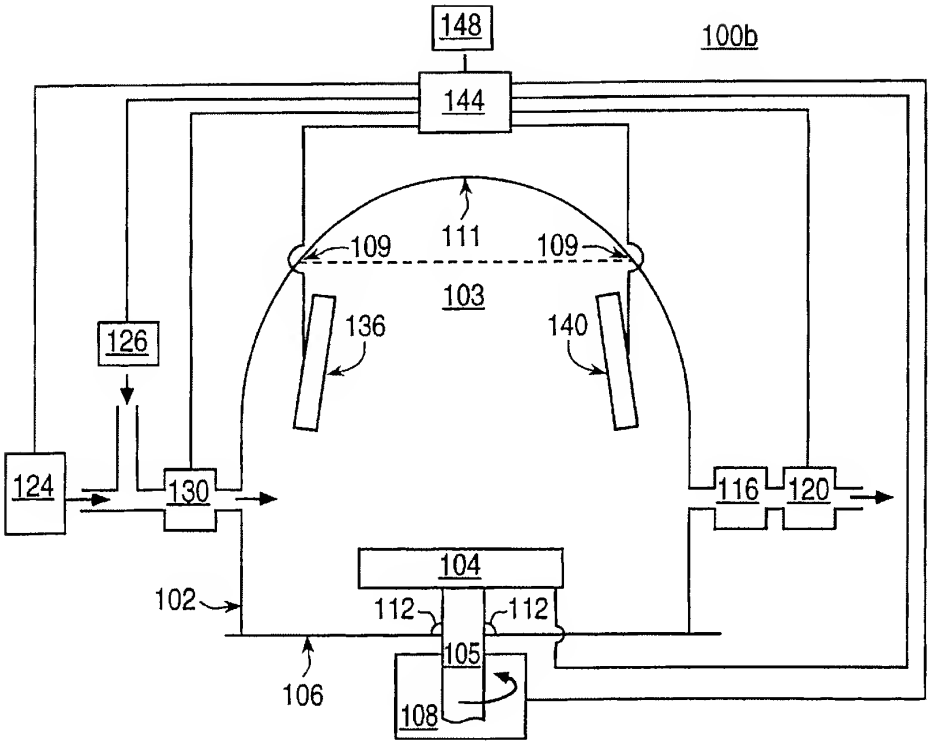

148
100b
144
111
109
109
103
136
140
126
124
130
116
120
104
102
112
112
105
106
108

FIG. 1b

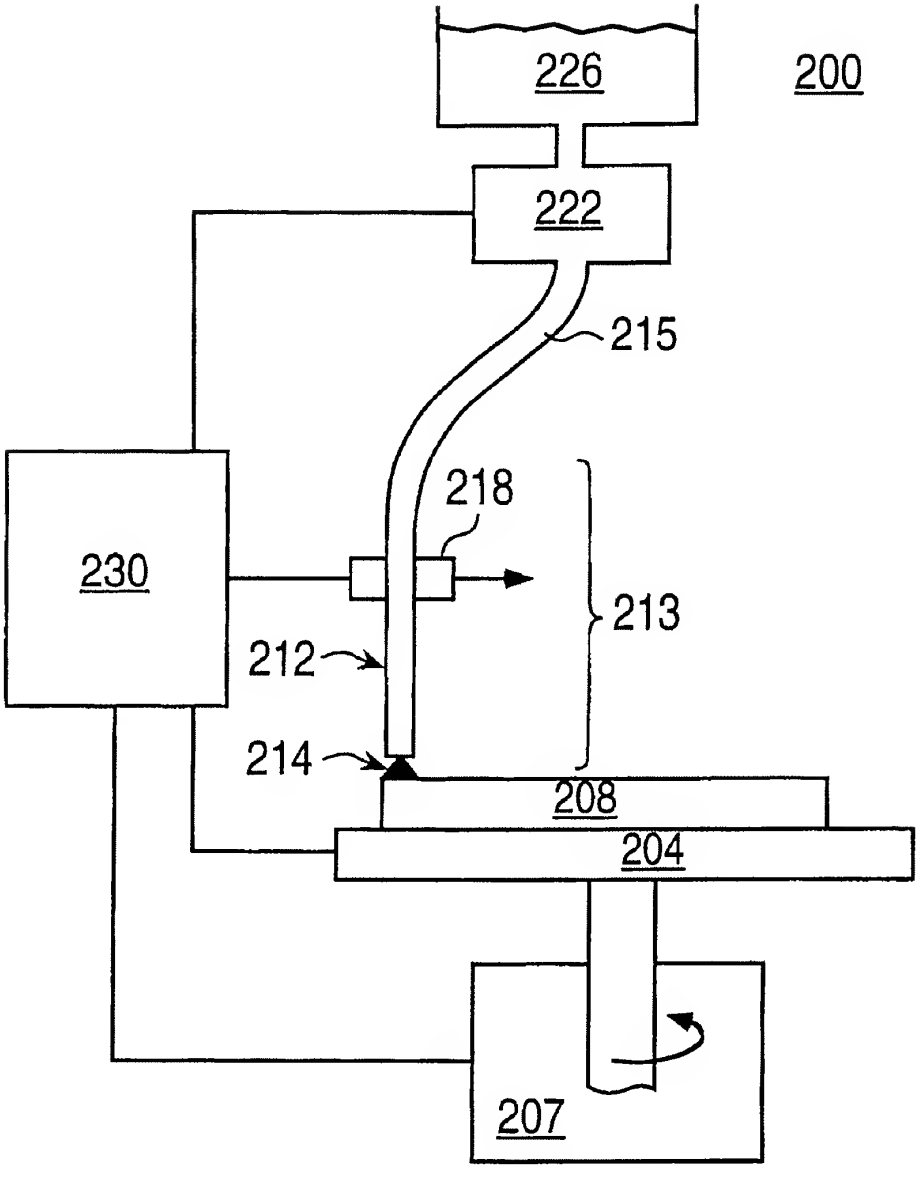



FIG. 2

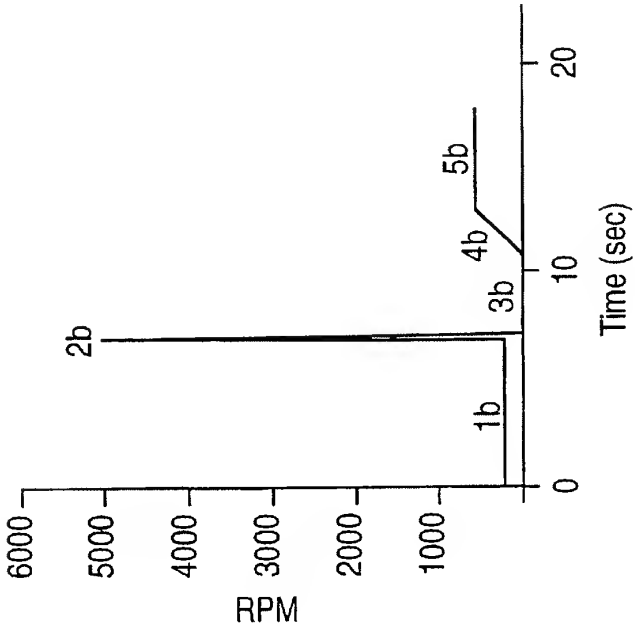

6000
5000
4000
3000
2000
1000
RPM
0
10
20
Time (sec)
1b
2b
3b
4b
5b

FIG. 3b

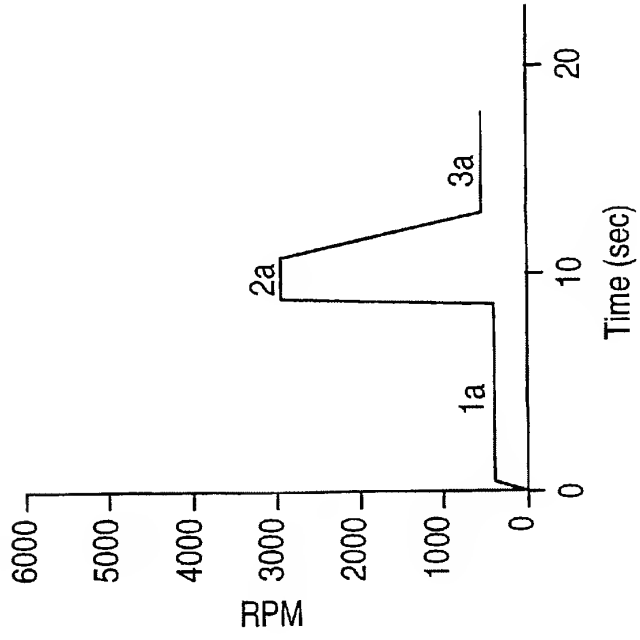

6000
5000
4000
3000
2000
1000
0
RPM
0
10
20
Time (sec)
1a
2a
3a

FIG. 3a


FIG. 4a




FIG. 4c




FIG. 4b

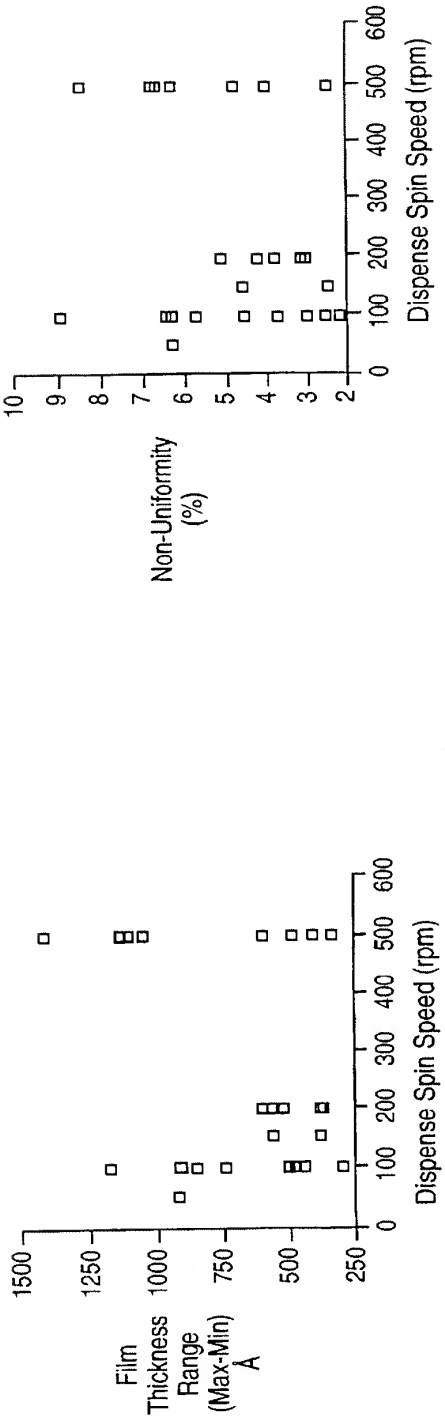



FIG. 5a

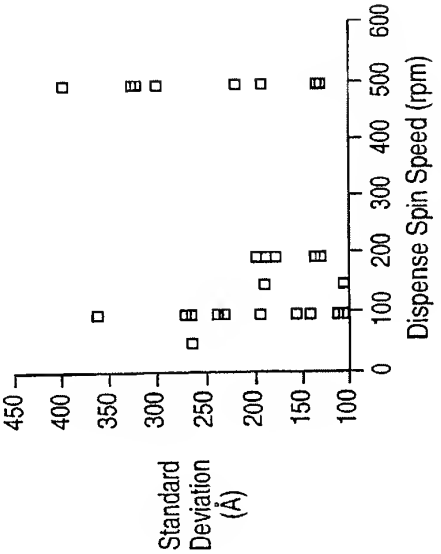



FIG. 5b




FIG. 5c

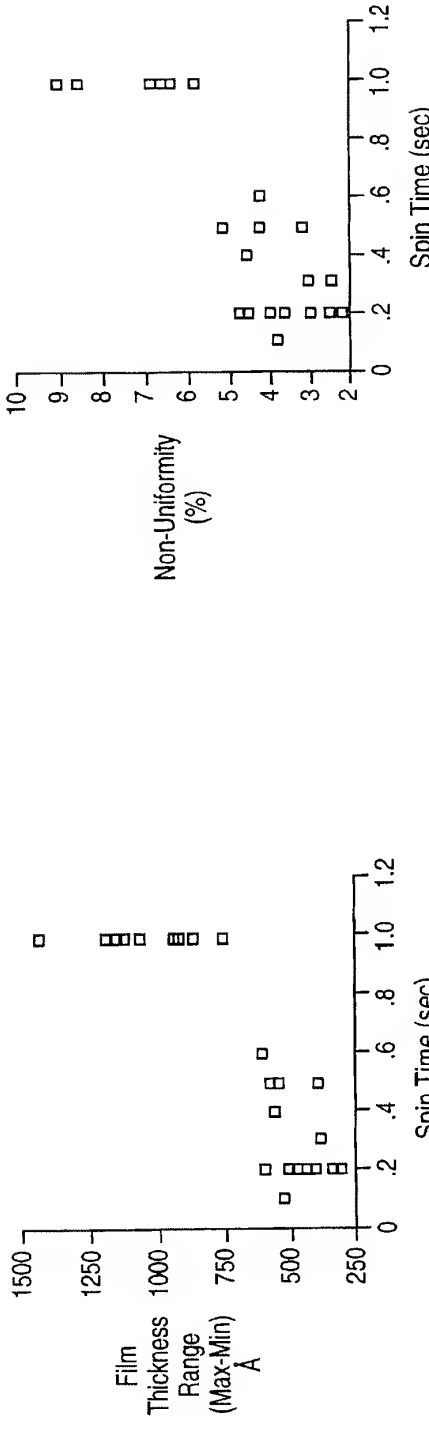



FIG. 6a

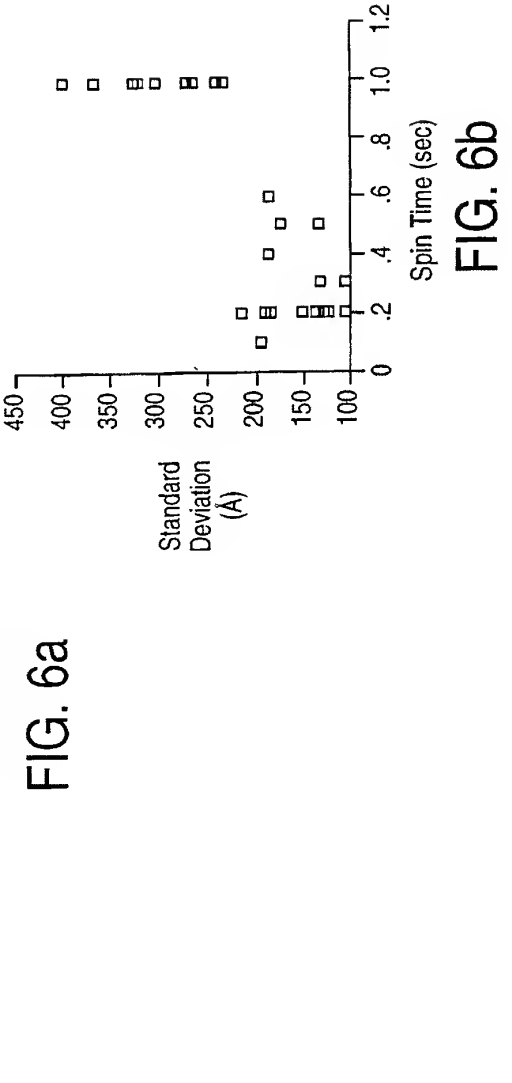



FIG. 6b




FIG. 6c

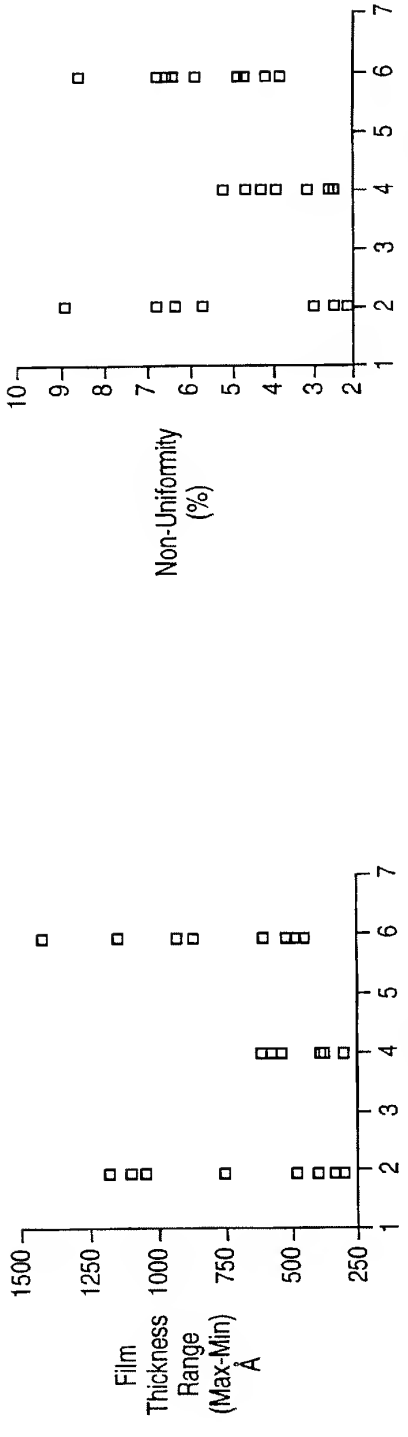



FIG. 7a

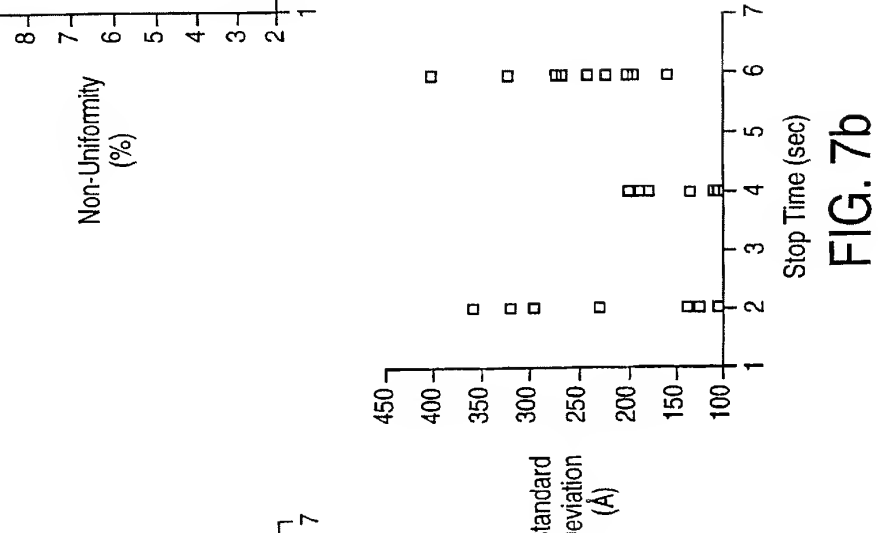



FIG. 7b




FIG. 7c

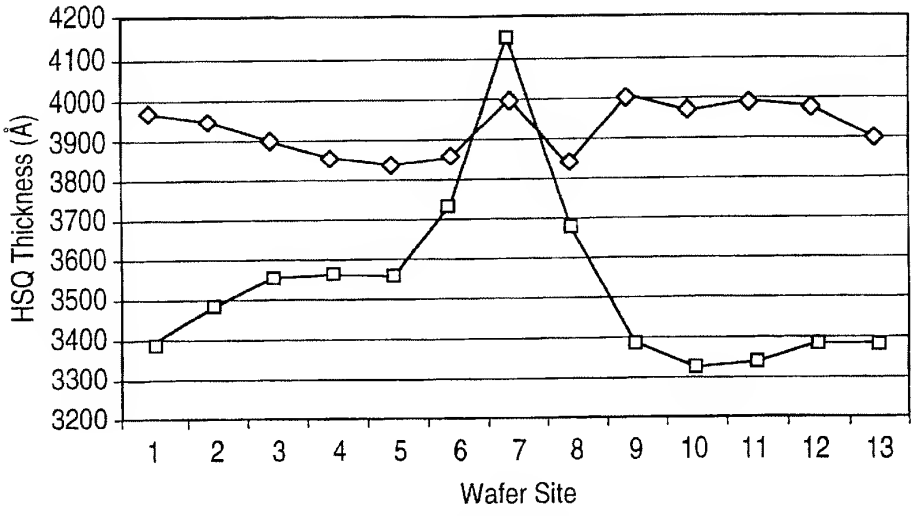



FIG. 8a

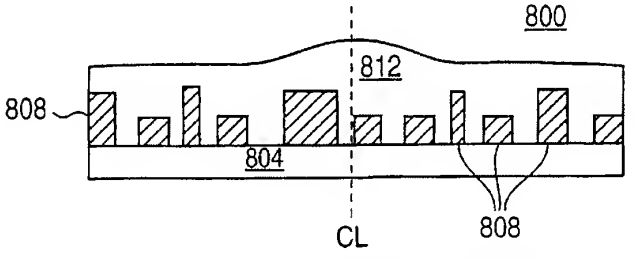



FIG. 8b (Prior Art)

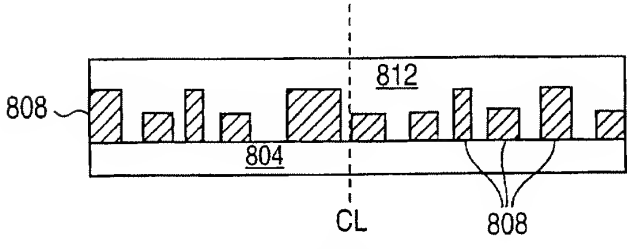



FIG. 8c

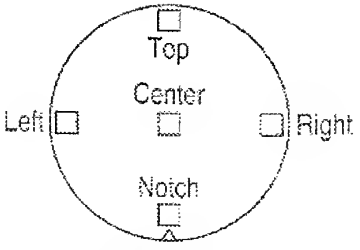



FIG. 9a

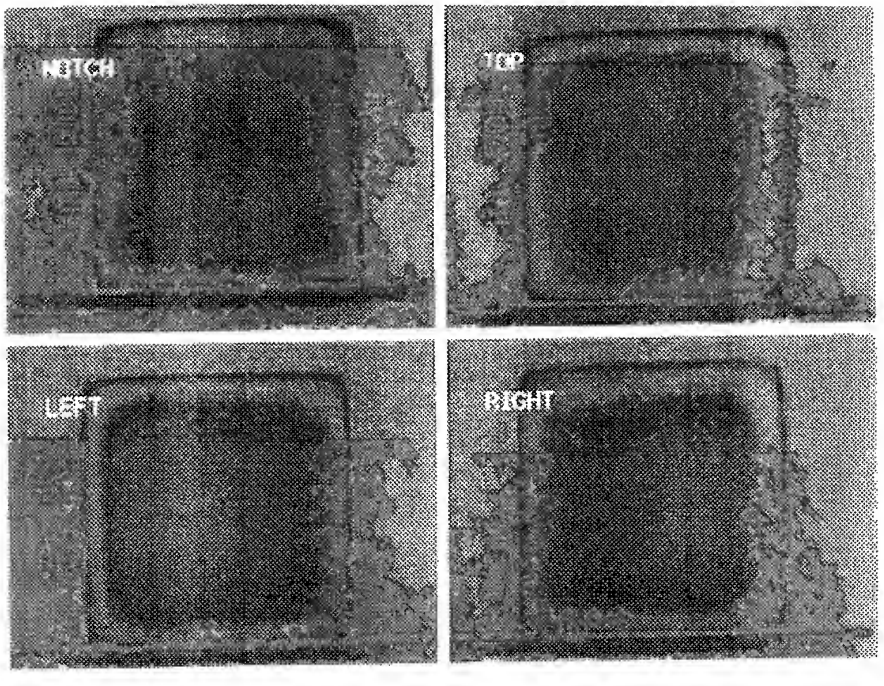



FIG. 9b (Prior Art)

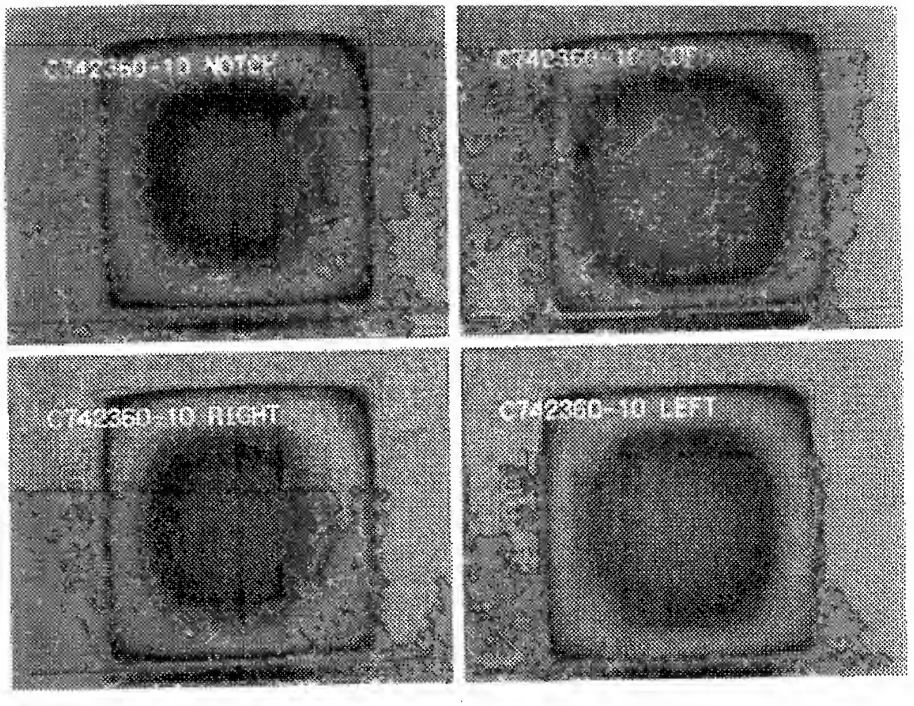



FIG. 9c

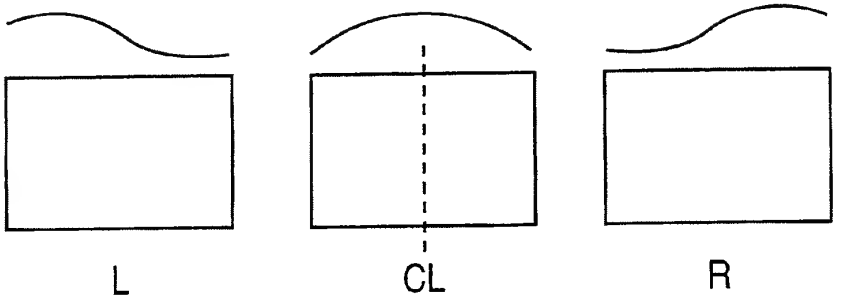



FIG. 10a (Prior Art)

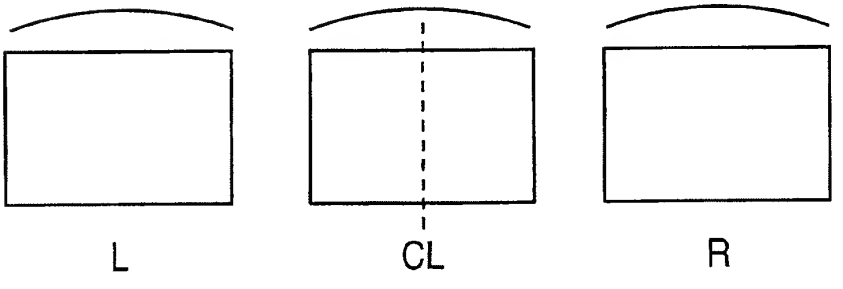



FIG. 10b

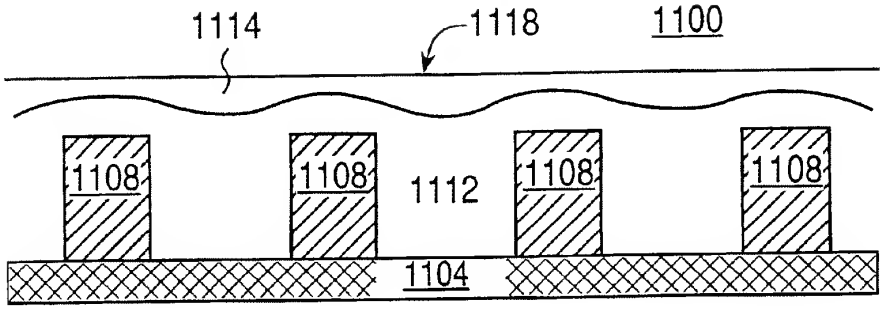



FIG. 11a

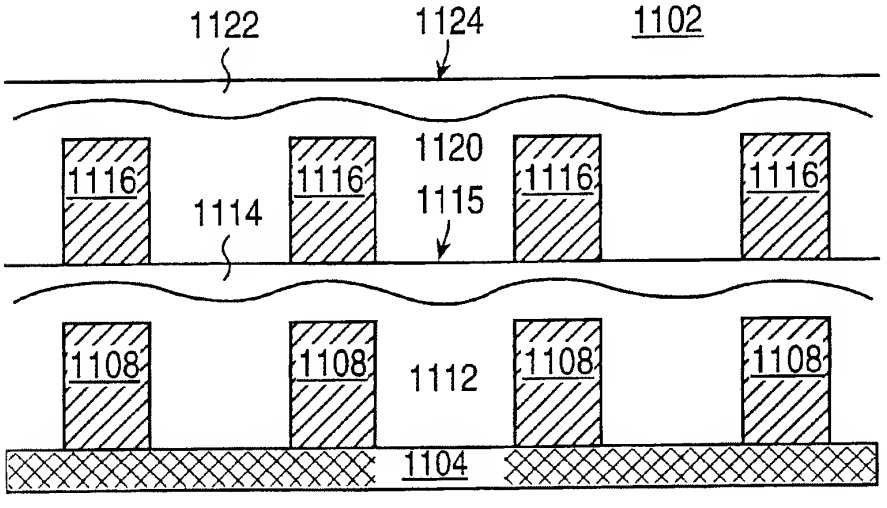



FIG. 11b

# METHODS OF MANUFACTURE OF UNIFORM SPIN-ON FILMS

## CROSS-REFERENCE TO RELATED APPLICATIONS

U.S. patent application Ser. No.: 09/196,721, entitled: "Closed Deposition Apparatus and Methods for Regulating Drying of Spin-On Films." Inventors: Lu You, Dawn Hopper, Richard J. Huang. Filed: Nov. 12, 1998.

U.S. patent application Ser. No.: 09/191,438, entitled: "Apparatus and Methods for Uniform Scan Dispensing of Spin-On Films." Inventors: Lu You, Dawn Hopper, Christof Streck, John Pellerin, Richard J. Huang. Filed: Nov. 12, 1998.

U.S. patent application Ser. No.: 09/191,101, U.S. Pat. No. 6,225,240 entitled: "Rapid Acceleration Methods for Global Planarization of Spin-On Films." Inventors: Lu You, Dawn Hopper, Richard J. Huang. Filed: Nov. 12, 1998.

U.S. patent application Ser. No.: 09/191,435, entitled: "Solution Flow-In for Uniform Deposition of Spin-On Films." Inventors; Lu You, Dawn Hopper, Richard J. Huang. Filed: Nov. 12, 1998.

U.S. patent application Ser. No.: 09/191,430, entitled: "Semiconductor Devices Having Spin-On Thin Films With Global and Local Planarity." Inventors: Lu You, Dawn Hopper, Richard J. Huang. Filed: Nov. 12, 1998.

U.S. patent application Ser. No.: 09/191,040, U.S. Pat. No. 6,200,913 entitled: "Cure Process for Manufacture of Low Dielectric Constant Interlevel Dielectric Layers." Inventors: Lu You, Simon Chan, John Iacoponi, Richard J. Huang, Rohin Cheung. Filed: Nov. 12, 1998.

Each of the above-identified patent applications is herein incorporated fully by reference.

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to the field of manufacturing thin films using spin-on methods. Specifically, this invention relates to (1) the manufacture of low dielectric constant layers for insulation of metal interconnects in semiconductor devices and (2) photoresist layers. More specifically, the invention relates to apparatus for and methods for improving the quality of spin-on thin films, including the use of a processor to regulate the deposition of spin-on films.

2. Discussion of the Related Art

Spin-on deposition methods are used for the manufacture of thin films on semiconductor devices. Generally, a solution comprising a solvent and a precursor of the material to be deposited is placed in the center of a semiconductor wafer and then the wafer is rotated at a rate sufficient to distribute the solution across the surface of the wafer (a "rapid spin step"). The amount of solution, the solution viscosity, the solvent evaporation rate, the acceleration and the maximum spinning speed determine, in general, the thickness of the spin-on coating.

The deposition of low dielectric constant materials such as glass and glass-like materials have also been deposited by spin-on methods. These spin-on-glass (SOG) methods generally involve the placement of a pool or puddle of a solution comprising a silicate or other precursor and an solvent such as an alcohol on the center of a semiconductor wafer. Typically, for a wafer with a diameter of 8 inches, about 4 ml of solution is used. The wafer is then rotated to distribute the solution over the wafer surface. During spinning, as the solvents evaporate, residual material, including by way of example only, an $SiO_2$-like layer, is deposited on the wafer. Typically, spin-on processes have been carried out at atmospheric pressure under ambient conditions, such as in air. For certain precursor solutions containing solvents with high volatility, solvent can evaporate so rapidly as to cause the spin-on layer to solidify before all of the thinning and evening steps have been completed. For these materials, the resulting spin-on layers are not ideally suited for manufacture of semiconductor devices. Layers deposited in this fashion can have non-uniformities of 20% or greater when deposited on patterned wafers with metal interconnects. For future integrated circuit manufacture, however, this non-uniformity presents a significant problem. This is true especially in the manufacture of multi-layered films. Each layer contributes its own nonuniformity to the multilayered film, and because the nonuniformity tends to be in the form of a thicker layer at the center of the wafer, the overall nonuniformity increases with the number of layers.

As a result of these problems, these processes are suitable for the manufacture of semiconductor devices with gap dimensions of greater than 0.5 $\mu$m. For purposes of this application, the term gap dimensions means the distance separating integrated circuit elements, for example, metal lines. Thus, filling the gaps between semiconductor elements requires that the deposition process provide dielectric material which can penetrate into the recesses of the gap. Conventional spin-on methods are not suited for manufacturing devices with gap dimensions of less than 0.5 $\mu$m. First, dispensing of a puddle of solution onto the middle of the wafer creates less complete coverage at the edges of the wafer. To counteract this problem, the puddle typically includes substantially more solution than is necessary to provide an even layer of solution over the wafer. During the rapid spinning step, more of the solution is spun off of the wafer, resulting in substantial loss of expensive precursors and environmentally harmful solvents. Next, as gaps in the metal interconnect pattern become narrower, it is more difficult to evenly fill the gaps, especially as the solution is distributed radially across the surface with a high velocity. Furthermore, as the solution is distributed radially, the solvent evaporates from the solution. This can lead to changes in the concentration of precursor in the solution and/or the viscosity of the solution as it is being distributed across the wafer.

These features of the prior art methods result in poor planarity of the surface, which can reduce the accuracy of subsequent manufacturing steps. The resulting semiconductor devices then can have low reliability. These problems have limited the minimum size of features which can be coated using spin-on methods.

Conventional solutions to these problems included the use of greater amounts of spin-on solution or the use of longer spin times. However, the use of more solution results in higher losses of chemicals, and longer spin times reduces the through-put in the wafer manufacturing process.

Certain types of dielectric materials can be cross-linked after deposition to increase the mechanical strength of the resulting thin film. However, prior art methods usually involve rapid temperature increases, which can result in thermomechanical stress being placed on the film. Mechanical stresses can weaken the film and can lead to increases in dielectric constant and decreased dielectric strength. These effects can result in decreased useful lifetimes of the thin films.

## SUMMARY OF THE INVENTION

Therefore, one object of this invention is the manufacture of spin-on layers with improved planarity on metal interconnect patterned wafers.

Another object of the invention is the manufacture of spin-on layers with better gap filling properties.

A further object of the invention is the manufacture of spin-on layers with more even deposition.

Yet another object of the invention is the manufacture of thinner spin-on layers.

An additional object of the invention is the manufacture of spin-on layers which produce less chemical waste.

A yet additional object of the invention is the manufacture of spin-on layers which are more rapidly manufactured.

A further object of the invention is the manufacture of spin-on layers with low dielectric constant, high dielectric strength, and high mechanical strength.

In one embodiment, the instant invention provides methods for manufacturing more uniform spin-on layers by improving the dispensing of spin-on solutions to achieve even layers of solutions of precursors of semiconductor thin films.

In one aspect of the invention, the improved methods for dispensing precursor solutions over the wafer surface are carried out wherein the precursor solution is pumped through a nozzle positioned over the wafer which is rotated at the same time as the nozzle is moved between the edge of the wafer and the wafer center, thereby providing a continuous layer of precursor solution on the wafer prior to the rapid spin step.

A further aspect of the invention is the deposition of precursor solutions from the outside edge of the wafer toward the center, thereby providing a more even layer of precursor solution prior to the rapid spinning step.

Another aspect of the invention is the regulation of the precursor dispensation using a processor to independently control the flow rate of precursor solution, wafer rotation velocity and/or dispensing nozzle velocity as the wafer is rotated, to provide an even layer of precursor solution on the wafer.

An additional embodiment of the invention is the use of high rates of acceleration during the rapid spinning step, high maximum rotation speed, high rates of deceleration, and reduced spin durations to distribute and thin the precursor solution, thereby resulting in a more even, thinner spin-on layer.

A further embodiment of the invention is the use of a solution flow-in period, wherein after the rapid spin step the wafer rotation is slowed to permit the precursor solution to spread evenly on the semiconductor wafer, and to provide improved planarity of the surface of the resulting thin film.

Yet another embodiment of the invention is the use of a closed deposition system to regulate the rates of evaporation of solvents during the dispensing, rapid spin, solution flow-in, and evaporation steps.

Another aspect of this invention is the regulation of solvent vapor pressure to control the rates of evaporation of solvent.

A yet further aspect of the invention is the use of increased deposition chamber pressure to decrease the rate of solvent evaporation during dispensation, rapid spin, and flow-in steps.

A yet further aspect of the invention is the use of decreased deposition pressure to improve the filling of gaps and to decrease the time necessary for evaporation of solvents.

An additional aspect of the invention is the use of reduced solvent pressure to increase the rate of evaporation during evaporation and curing steps.

A further aspect of the invention is the use of a processor to coordinate and regulate dispensation, deposition chamber conditions, flow-in, rapid spin, evaporation, and/or curing steps.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1***a* and **1***b* are block diagrams two deposition chambers used for the manufacture of spin-on thin films of this invention.

FIG. **2** is a block diagram of the apparatus used to dispense the spin-on solutions of this invention.

FIG. **3***a* is a graph of spin speed versus time for one embodiment of the invention.

FIG. **3***b* is a graph of spin speed versus time for another embodiment of the invention.

FIGS. **4***a*, **4***b* and **4***c* are plots showing the relationships between film thickness range, standard deviation and film non-uniformity, respectively, and the dispense time of the precursor solution for thin films deposited on metal patterned wafers.

FIGS. **5***a*, **5***b* and **5***c* are plots showing the relationships between film thickness range, standard deviation and film non-uniformity, respectively, and the dispense spin speed for thin films deposited on metal patterned wafers.

FIGS. **6***a*, **6***b* and **6***c* are plots showing the relationships between film thickness range, standard deviation and film non-uniformity, respectively, and the spin time after dispensation for thin films deposited on metal patterned wafers.

FIGS. **7***a*, **7***b* and **7***c* are plots showing the relationships between film thickness range, standard deviation and film non-uniformity, respectively, and the stop time after dispensation for thin films deposited on metal patterned wafers.

FIG. **8***a* shows the thickness of a thin film of this invention deposited plotted as a function of the distance from the center of a patterned wafer.

FIG. **8***b* depicts a spin-on layer deposited using a center-dispense method.

FIG. **8***c* depicts a spin-on layer deposited using the edge-dispense method of this invention.

FIG. **9***a* depicts a semiconductor wafer with four areas selected for measuring the film thickness.

FIGS. **9***b* and **9***c* show photographs of the surfaces of wafers containing semiconductor thin films deposited using standard methods (FIG. **9***b*) and the edge-dispense methods of this invention (FIG. **9***c*), respectively.

FIG. **10***a* depicts the local non-uniformity of thin films deposited using conventional spin-on methods.

FIG. **10***b* depicts the local non-uniformity of thin films deposited using the spin-on methods of this invention.

FIGS. **11***a* and **11***b* depict single level and multilevel semiconductor devices, respectively, comprising thin films of this invention.

## DETAILED DESCRIPTION OF THE INVENTION

This invention solves the problems in the prior art methods for spin-on-deposition by separately regulating the steps in the manufacturing process to provide an even, high quality thin film on a substrate surface. The improved steps in the manufacture of spin-on films include the use of: (1) a closed deposition chamber, whereby the conditions of spin-on deposition can be regulated; (2) the dispensing of precursor solutions in fashions to provide an even layer of

precursor solution distributed over the entire wafer surface prior to the rapid spinning step; (3) the use of rapid acceleration, high maximum wafer rotation speed and high rates of deceleration to even and thin the precursor solution; (4) a period of solution flow-in after the rapid spinning step to permit the precursor solution to distribute over the wafer surface more evenly; and (5) control over the solvent evaporation and curing steps of the thin film. Any type of film which can normally be deposited in solution can be deposited advantageously using the apparatus and methods of this invention. Such layers include but are not limited to photoresist layers and low dielectric constant films.

### 1. Closed Deposition Chamber for Spin-On Deposition

The improved processes of this invention can be advantageously carried out in a closed deposition chamber containing the wafer, the chuck, ports for introducing precursor solutions, environmental gases, and devices for regulating pressure and temperature during the manufacturing processes. The deposition apparatus shown in FIG. **1***a* comprises a deposition chamber **100***a* comprising a bell **102** sealed onto a support platform **106** with seals **110** capable of containing the gases in the chamber space **103** during the low and high pressures that exist during deposition of the spin-on materials. The bell **102** can be made of any convenient material which is inert to the chemicals used in spin-on deposition. Such materials can be, by way of example only, quartz, glass or stainless steel. The size of the bell should be sufficient to enclose the chuck, wafer, and can also, if desired, accommodate the solution dispensing apparatus for scan dispensing spin-on solutions. A pump **120** is used to decrease the pressure in chamber space **103** if desired, and to exhaust gases from the chamber. A cold trap **116** is used to prevent solvents and/or precursors from contaminating the pump **120** and to prevent environmental contamination.

The gas composition within chamber space **103** can be regulated by a bias gas inflow source **124**, which typically uses an inert gas such as nitrogen, helium, argon or similar gas. Inert gases can minimize the oxidation of the dielectric material, thereby decreasing the dielectric constant of the resulting thin film. To increase the solvent vapor pressure in chamber space **103**, a solvent injector **130** is used. Solvent injector can be a bubbler to volatilize liquid solvents, or an injector to directly place solvent into the bias gas flowing into the deposition chamber. These types of solvent injection devices are known in the art and will not be described further. The temperature inside the deposition chamber can be increased by heaters **136** or can be decreased by coolers **140**. The heaters can be any conventional type, including resistive heaters or infrared lamps known in the art. Coolers **140** can be radiative coolers using cold air, cooling liquids such as, by way of example only, freons or other refrigerants such as cold water. A chuck **104** capable of rotation about its central axis is shown. The spindle **105** is typically sealed using a gasket **112**, which can be made of any chemically inert material suitable for maintaining the pressure within the chamber space **103**. By way of example only, the gasket **112** can be made of stainless steel, silicone polymers, or other materials known in the art. The evaporation of solvents from the wafer can be slowed by cooling the wafer and chuck **104** by conventional means, by way of example only, the reverse Peltier effect. Alternatively, the chuck **104** can be cooled using a cooling fluid such as, by way of example only, cold water, freons and other refrigerants, or cold air. Alternatively, the chamber space **103** can be cooled adiabatically by using the bias gas stored under pressure and released into the chamber at a pressure lower than the storage pressure of the gas. Further adiabatic cooling can be accomplished by lowering the pressure in the chamber space **103** using pump **120**. Moreover, the temperature in the chamber space **103** can be decreased using a cooled bias gas **126**.

The pump **120**, bias gas inflow apparatus **124**, bias cooling gas **126**, the solvent injector **130**, the heaters **136** and coolers **140**, and the chuck cooling devices can be separately controlled using a processor **144** which can be attached to a memory device **148** which can store a program to regulate the conditions within the chamber space **103**, the rotation, and the temperature of the chuck **104**. In operation, the bell **102** can be raised to permit the installation of a wafer on chuck **104**. The bell is then lowered onto platform **106** and the pressure is maintained by seals **110**. Within the closed deposition chamber the physical and chemical conditions for the deposition are adjusted as desired. After deposition of a spin-on layer, the bell **102** is raised and the wafer removed for subsequent processing.

In an alternative embodiment, shown in FIG. **1***b*, the deposition chamber can be designed with the lower portion of the device being made as a unit, with the base **106**, sidewalls of the bell **102**, the bias flow port and the pump port, the heaters **136** and coolers **140** being attached to the base **106**. In this embodiment, a removable top portion **111** is provided to permit access to the interior of the deposition chamber. When a wafer is placed on the chuck **104**, the top **111** is lowered onto sidewalls **102**, and seals **109** maintain the pressure within the chamber space **103**.

In operation, a wafer can be placed on the chuck **104**, and can have an aliquot of precursor solution placed on the wafer. The deposition chamber can be closed and the temperature, pressure, and gas composition can be set to desired conditions for the spin steps. The application of precursor solution can be by any method known in the art, but a preferred method is to apply the precursor solution using a scan-dispense methods of this invention described below (for example, FIG. **2**).

One of the advantages of this closed deposition system is the ability to regulate the evaporation of solvents during dispensing, rapid spinning, solution flow-in and solvent evaporation (drying) steps. If the solvent evaporation rates are too high, then the residual deposited material can crack, decreasing dielectric strength and mechanical strength. These changes result in shorter lifetimes for semiconductor devices.

For certain solvents with high volatility such as naphtha, methylisobutylketone (MIBK), or n-methylisobutylketone (NMIBK), the solvent can evaporate rapidly from the surface of the wafer where the solution was dispensed first, leaving behind a more viscous solution containing a higher concentration of dielectric precursor. In contrast, in areas of the wafer where the solution is dispensed later in time, there is less time for the solvent to evaporate, and the solution is therefore less concentrated and less viscous. During the subsequent rapid spinning step, the less viscous solution can spread to a higher degree than the more viscous solution. The differences in spreading behavior of the solutions with different viscosity can result in a build-up of materials in the middle of the wafer producing non-uniformity of the final spin-on layer. This is especially true for solutions dispensed form the center of the wafer to the outer edge.

Therefore, to slow the rate of evaporation, it is desirable to: 1) reduce the rotation speed of the wafer during the dispensation of precursor solution, 2) increase the pressure

within the deposition chamber, 3) increase the partial pressure of the solvent in the deposition chamber, and/or 4) reduce the temperature of either the deposition chamber or the wafer. Reducing the rate of evaporation of solvent from the solution minimizes the increase in precursor concentration and viscosity of the spin-on solution. As a result, the solution can be thinned and evened in a more controlled fashion.

A. Regulation of Rotation Speed.

One way to reduce the rate of evaporation of solvents from a wafer is to select a slow rotation speed during the dispensing step. By using a slow rotation speed, there can be less exchange of bulk chamber gas with the layers of gas near the wafer's surface. At low rotation speeds, the concentration of solvent can increase in the layers near the wafer surface, thus providing an increased rate of diffusion of solvent from the gas phase to the liquid phase on the wafer. This decreases the net rate of solvent loss from the wafer surface. Typically, during dispensation using the present system, the wafer rotation speed is in the range of about 100 rpm to about 500 rpm, in one example, about 200 rpm.

B. Regulation of Pressure Within the Deposition Chamber.

Another way of slowing solvent evaporation is to select a pressure greater than atmospheric pressure within the deposition chamber. Increasing the total pressure of gas reduces the concentration of solvent in the gas phase necessary to reach a given vapor pressure. Thus, the diffusion of solvent gas back into the liquid phase on the wafer surface is increased by increasing total pressure. Therefore, in one aspect of this invention for solvents with high volatility, it can be advantageous to increase the pressure in the chamber from about 760 Torr (1 atmosphere) to about 1520 Torr (2 atmospheres), and in one example, in the range of about 1140 Torr (1.5 atmospheres) to about 1520 Torr (2 atmospheres), and in another example about 1520 Torr (2 atmospheres).

C. Regulation of Solvent Vapor Pressure.

Alternatively, in another aspect of the invention for use with highly volatile solvents, it can be advantageous to add solvent into the deposition chamber to provide an increased solvent vapor partial pressure. This can be done using the solvent injector **130**. It is advantageous to use solvent vapor pressures in the range of greater than about 0% of the ambient pressure to about 99% of the ambient pressure, in one example in the range of about 10% to about 90%, in another example from about 40% to about 60%, and in yet another example from about 20% to about 30%. However, it can be appreciated that solvents with lower volatility do not require the vapor partial pressure to be as high as that for solvents with a higher volatility to achieve similarly reductions in the rates of solvent evaporation.

D. Regulation of Chamber Temperature.

Moreover, in another aspect of this invention, decreasing the temperature within the chamber to below room temperature also can reduce the evaporation of solvents which are highly volatile at room temperature. In general, to decrease the evaporation rates of solvents commonly used for spin-on deposition, it is advantageous to carry out deposition steps at a temperature to below about ¾ of the boiling point of the solvent in Kelvins. Thus, for a solvent such as methylisobutylketone, whose boiling temperature is about 423 Kelvins (150° C.), maintaining chamber temperature in the range of about 253 Kelvins (−20° C.) to about 293 Kelvins (about 20° C.), and in a specific example, about 283 Kelvins (10° C.) provides for an evaporation rate sufficiently low to permit proper thinning during the rapid spin step. Moreover, for many precursor/solvent solutions, decreasing the temperature can increase the viscosity of the solution. If the temperature is decreased too much, the viscosity of the solution can increase too much, and the handling the solutions, including the dispensing steps can become difficult. Conversely, for solvents which are not as volatile as naphtha or methylisobutylketone, a higher temperature in the chamber can be advantageously used without an undesirably high rate of evaporation. Therefore, it is desirable to choose conditions of wafer rotation speed, pressure, temperature and solvent vapor partial pressure to optimize the dispensation and thinning of spin-on solutions.

II. Dispensing Spin-On Solutions

A. Selection of Solutions.

Any material in solution form can be applied using the method of this invention. However, for application of low dielectric constant dielectrics, the precursor hydrogen silsesquioxane (HSQ) is suitable. In addition to HSQ, other low dielectric constant materials can be scan spin dispensed using the methods of this invention include, by way of example only, benzylcyclobutene (BCB), perfluorocyclobutene (PFCB), poly(arylene)ethers, fluorinated poly(arylene)ethers, polyimides, fluorinated polyimides, poly(tetrafluoroethylene), polyethylene, and hybrid-silsesquioxanes.

Any solvent known in the art to dissolve a selected precursor can be used using these methods. In general, it is desirable to select a solvent which is environmentally safe, can solubilize the precursor to achieve a solution of the desired precursor concentration, is commercially available, and can evaporate sufficiently rapidly. The typical solvents used for dissolving spin-on glass, HSQ, BCB, poly(arylene) ethers, and fluorinated poly(arylene)ethers include, by way of example only, isopropanol, naphtha, MIBK, NMIBK, and mesitylene, among others. Additionally, any other solvent which can sufficiently dissolve the precursor, and can be removed from the surface by evaporation can also be used.

The concentration of solute can be varied to suit the particular needs of the user. For example, solutions with lower viscosity and higher wetting properties can flow into gaps more easily than solutions with higher viscosity and lower wetting properties. Moreover, solutions with higher viscosity have a greater tendency to remain at the site of dispensation than solutions with lower viscosity. Because during spinning, the acceleration is greater near the edge of the spinning wafer than in the center of the wafer, solution nearer the edge is subjected to higher acceleration, than the solution nearer the center. Thus, films tend to be thinner near the edge of the wafer and thicker near the center of the wafer. Typical solutions include HSQ in MIBK in a concentration range of from about 1% to about 70%, alternatively from about 5% to about 50%, an another example from about 10% to about 20% and in yet another example, about 15%.

B. Scan Dispensing Solutions Onto Wafers.

Another embodiment of this invention is a novel process for dispensing the solution in a more controlled fashion than previous methods (the "scan dispensing" method). For certain precursors such as HSQ and solvents such as naphtha and methylisobutylketone which are volatile, evaporation begins immediately after a portion of solution is dispensed onto the wafer. If the solution is dispensed beginning from the center of the wafer, as is typical of prior art methods, the result is an area of partially dried precursor in the middle of the wafer. As the wafer is subsequently rapidly spun, the centrifugal forces are less at the center of the wafer, and therefore, the layer of solution in the middle of the wafer is thinned to a much lesser degree. This results in a spin-on film that is thicker at the wafer middle and therefore is not planar.

To improve the planarity of the spin-on material, in this embodiment of the invention, the solution can be scan dispensed to substantially cover the wafer prior to the rapid spin step. FIG. **2** depicts apparatus used to dispense spin-on coatings of the invention. Chuck **204** can be cooled using methods known in the art, such as the reverse Peltier effect or fluid cooling, using, for example, freons, cooled water, or other refrigerants known in the art. Chuck **204** is adapted to hold wafer **208** which has an upper surface on which the spin-on layer is to be deposited. The chuck and wafer are depicted as rotating in the direction of the curved arrow. The chuck and wafer are rotated by motor **207**. Dispensing nozzle **212** provides the flow of precursor solution to form a bead **214** on the wafer. The dispensing nozzle **212** is part of a dispensing arm **213** which is moved by a dispensing arm actuator **218** which moves the dispensing arm and nozzle **212** radially across wafer **208** as shown by the linear arrow. The solution is provided by reservoir **226** and is fed into the dispensing arm **213** by a pump **222**. The precursor solution flows through flexible tube **215** and into the dispensing nozzle **212**.

The movement of dispensing nozzle **212** can be in either the centripital direction shown, from the edge of the wafer to the center, or in a centrifugal direction, from the center of the wafer to the edge. The movement of dispensing arm actuator **218** can be controlled by processor **230**, for example, a microprocessor which is capable of running a program stored in a memory device (not shown) to enable the desired movement of dispensing arm **212** over wafer **208** to dispense a bead **214** of the desired width. The pump **222** can also be controlled by processor **230** to provide the desired flow rate of precursor solution through dispensing arm **212** through a nozzle and onto wafer **208** to dispense a bead **214** of the desired configuration. Moreover, the rotation velocity and the temperature of the chuck **204** and wafer **208** can be controlled by processor **230** during the dispensing step to regulated the thickness of the bead of solution.

Optionally, dispensing arm **212**, pump **222**, and/or chuck **204** can be regulated in a coordinated fashion to permit the simultaneous regulation of the movement of dispensing arm actuator **218**, the flow rate of pump **222**, and/or chuck **204** to achieve the desired configuration of bead **214**.

In one aspect of this embodiment, the solution is deposited first near the edge of the wafer, and the solution is progressively deposited toward the center of the wafer ("edge scan dispense" method; see Example 1). The solution can be advantageously dispensed onto the wafer while the wafer is rotating at a low rate of speed. During dispensation, the dispensing nozzle **212** moves toward the center of the wafer, thus resulting in a spiral-shaped bead of solution **214** covering the surface of the wafer.

For certain highly volatile solvents such as naphtha or methylisobutylketone, by depositing the solution first at the outer edge, evaporation of solvent after dispensing can result in a more viscous layer of material at the outer edge of the wafer. This is because as the dispensing arm moves progressively toward the center of the wafer, there is progressively less time available for solvent evaporation for the first-dispensed solution compared to the later-dispensed solution. This results in an uneven distribution of precursor concentration in the dispensed solution, with a parallel, uneven viscosity of the layer decreasing progressively toward tbe center of the wafer. Thereafter, during the rapid spinning step, where the centrifugal forces are highest at the periphery of the wafer, the layer of solution is more viscous and more consolidated, and therefore does not thin as much as in prior art methods. In contrast, at the center of the wafer, where the centrifugal forces are smaller than at the outer edge, the solution is less viscous, and is thinned more easily. Thus, the differences in viscosity of the solution at the edge compared to the center of the wafer at least partially compensates for the differences in centrifugal forces to which the solution is subjected, and as a result, the within wafer non-uniformity of the thickness of the thin film is substantially reduced, thereby improving the quality of the spin-on thin film.

For certain other solvents which are not as volatile as methylisobutylketone, it can be desirable to dispense an even layer of solution on the wafer prior to the rapid spinning step. Using the methods of this invention, the amount of solution dispensed on each portion of the wafer can be carefully regulated, thereby resulting in a layer of solution of uniform thickness.

The speed with which the nozzle moves between the center and edge of the wafer and the rotation velocity of the wafer determines the distance between successive lines of the spiral bead of solution. For a given nozzle velocity, as the speed of wafer rotation increases, the distance between the successive beads of solution decreases. Moreover, for a given wafer rotation speed, increasing the velocity of nozzle movement increases the distance between beads. Further, as the flow rate of solution from the nozzle increases, the width of the solution bead increases. By increasing bead width, the distance between successively applied beads of precursor solution can be increased without resulting in the formation of spaces of precursor-free wafer between the successively applied beads. In general, it is desirable to provide an even, complete layer of solution prior to the high speed spin step. Thus, during the solution dispensing step, the rotation speed, solution flow rate and nozzle speed are controlled so that the edges of the bead of solution overlap the edges of adjacent beads. By completely covering the wafer, the solution has opportunity to penetrate into the gaps in the features to provide better coverage and adherence of final film to the wafer.

The control over the thickness and evenness of the dispensed solution can be regulated by controlling: 1) precursor solution flow rate, 2) movement of the dispensing nozzle over the wafer, 3) wafer rotation speed, and 4) the rate of evaporation of solvent from the surface of the liquid film. By using these methods, it is possible to achieve global non-uniformity of a patterned wafer of less than about 20%. In fact, in some cases, the global non-uniformity can be 5% or less. In contrast, using methods of the prior art, global non-uniformity is much greater, being about 20% or higher. Thus, using the methods of this invention, global planarity can be improved by about 4 times or even greater.

1. Control of Dispensing Flow Rate.

The precursor solution can be dispensed onto the wafer using any convenient feed device, including, but not limited to conventional liquid pumps or gas-pressurized dispensing devices. Which type of feed device advantageously used can depend on the physical properties of the solution. For solutions which have a viscosity in the range below about 10 centipoise (cp), the preferred feed device comprises a pressurized solution reservoir with an inert feed gas, such as helium or nitrogen, to provide the pressure necessary to initiate and maintain solution flow onto the wafer. In this type of feed device, the solution flow rate is controlled by regulating the pressure of the feed gas within the reservoir. By way of example only, a typical low viscosity solution comprising about 10% to about 20% HSQ in methylisobutylketone has a viscosity in the range of about 5 to 7 cp. In contrast, for solutions which have a viscosity in the range of

above about 10 to 15 cp and higher, a feed device using a conventional liquid pump **222** and reservoir **226** is advantageously used (FIG. **2**). By way of example, a typical high viscosity solution can comprise about 20% to about 40% BCB in 1, 3, 5-trimethylbenzene. In a preferred embodiment using a gas-pressurized device, a reservoir of solution in a pressure-sealed chamber is overlayed with an inert gas such as helium, and the pressure in the dispensing chamber is increased by use of a pump or other pressure source. The flow rate of the solution out of the dispensing device is regulated by the gas pressure within the device. Increasing the pressure of the gas within the device increases the flow of solution out of the device. Additionally, a flow regulator can be used to provide further control over solution flow rate.

The pressure necessary to dispense the solution varies, with solutions of higher viscosity requiring higher pressures to generate the same flow rate as solutions with lower viscosity. Typically, dispensation pressures are in the range of from about 0.1 pounds per square inch (psi) to about 20 psi, alternatively from about 1 psi to about 10 psi, and in another example, from about 3 psi to about 4 psi.

When the nozzle reaches the center of the wafer, flow of solution ceases and the nozzle is removed from the wafer.

The flow rate of solution onto the wafer can vary, depending on the surface tension of the liquid and the wetting behavior of the solution on the wafer surface. With solutions with lower surface tension and/or better wetting behavior, less solution is required to achieve a desired bead width. Conversely, for solutions with higher surface tension and/or poorer wetting behavior, more solution will be needed to achieve a desired bead thickness. Typically, the desired solution flow rates are in the range of about 0.1 ml/min to about 20 ml/min, alternatively from about 1 ml/min to about 10 ml/min, and in another example, from about 3 ml/min to about 4 ml/min. for solutions of about 10% to about 20% HSQ in MIBK.

At a given flow rate, the duration of the dispense step can be varied to achieve the desired coverage of the wafer. In general, the duration of dispersing can vary, typically in the range of from about 100 $\mu$sec to about 30 sec, alternatively from about 100 $\mu$sec to about 10 sec, and in another example, about 2 seconds for HSQ/MIBK. By way of example only, Example 4, FIGS. **4***a*, **4***b* and **4***c* show the results of experiments to determine the optimum time for dispensing HSQ/MIBK solution. The range of film thickness (FIG. **4***a*), the standard deviation of the range (FIG. **4***b*) and the wafer non-uniformity (FIG. **4***c*) are minimized by using a dispense time of about 1.2 seconds. Using similar testing methods, it is routine to determine the optimum dispense time for any desired solution of solvent and precursor. Using similar test strategies, it is possible to determine the optimum dispensing time for any particular combination of solvent, precursor, and wafer size.

Within these ranges, to achieve an even thickness of solution on a wafer, it is necessary to have higher flow rates of solution applied to portions of the wafer near the edges. This is because the width of a bead of solution is smaller as the linear velocity of the wafer is higher near the wafer's edge. To achieve a consistent bead width and an even layer of solution, it can be advantageous for the ratio of solution flow rate to linear velocity of the wafer under the nozzle be held approximately constant. This can be accomplished by progressively decreasing the flow rate as the nozzle moves toward the center of the wafer. If a thinner layer of solution at the wafer center is desired, this can be accomplished by decreasing the flow rate even more, so that the ratio of flow rate to linear velocity of the wafer decreases as the nozzle moves to the center of the wafer. Alternatively, in those situations where the solution is dispensed beginning at the center of the wafer, the flow rate of solution can be progressively increased as the nozzle is moved more towards the wafer edge.

In alternative embodiments of the invention, the flow rate of the solution onto the wafer and/or the movement of the dispensing nozzle over the wafer surface during the step of dispensing can be controlled using a processor to control the dispensation of precursor solution to provide a desired thickness of solution on the wafer. The processor is attached to the dispensing arm actuator, a solution pump system, or both. In those embodiments in which the processor controls the dispensing pump, at the beginning of the dispensation step at the outer edge of the wafer, the flow rate of solution is adjusted to be sufficiently high to provide a desired bead thickness over the surface of the wafer at that location, which has a higher linear velocity relative to the linear velocity at sites more toward the center of the wafer. As the dispensation arm moves centripetally toward the wafer center, the linear velocity of the wafer under the dispensation arm decreases. Therefore, in one method of this invention, one can decrease the amount of solution to be pumped onto the wafer to maintain a desired bead thickness. When the dispensing arm reaches the center of the wafer, the flow rate of solution is decreased to about zero. Alternatively, if the solution is applied beginning at the middle of the wafer, the processor can be directed to increase the flow rate of solution as the dispensing arm is moved progressively more centrifugally toward the wafer edge.

The processor can use Algorithm 1 to provide output to the control elements of the apparatus.

$$D(t) = 2 \cdot \frac{AT}{R^2}(R - Va \cdot t), \qquad \text{Algorithm 1}$$

where

$$T = \frac{R}{Va}$$

and where:

D(t) is the dispense function wherein at the time of t=0, with the dispensing arm at the edge of the wafer, and where at the time of t=T, the dispense arm is at the center of the wafer. The variables in the dispense function are as follows:

A is a constant depending on the total volume of fluid dispensed onto the wafer;

t is the time in seconds;

T is the total time in seconds for dispensing the slurry;

R is the wafer diameter in meters; and

Va is the linear speed (in meters/sec) of the dispensing arm.

2. Regulation of Dispensing Arm Motion By Processor.

In an alternative embodiment in which the rate of movement of the dispensation arm is controlled by a processor, at the periphery of the wafer, the dispensation arm moves centripetally or centrifugally, and the speed of its movement is regulated to compensate for the different linear velocity of the wafer surface under the nozzle. At a given solution flow rate, because the linear velocity of the wafer under the dispensing arm is higher at the edge of the wafer, the bead of dispensed solution will be relatively narrow compared to

a bead dispensed onto a portion of the wafer which moves more slowly. Thus, in an embodiment in which the solution is applied first near the edge ("edge-scan dispense" method), to maintain overlapping beads on successive rotations of the wafer, while near the edge of the wafer the dispensing arm should be moved only slowly toward the center of the wafer. However, as the dispensing arm moves progressively centripetally, the linear velocity of the wafer under the arm decreases, so that at the same given flow rate of solution, the width of the bead will increase. Thus, the movement of the dispensation arm can be controlled to provide an increasing distance between successive head centers, which results in overlapping bead edges. Alternatively, if the solution is applied first near the center of the wafer, the rate of arm movement can he lower near the center than the rate of movement as the arm nears the wafer edge. R and Va are defined as above. Typically, the total time T (in seconds) for dispensing slurry, and the wafer rotation speed u (in rotations per minute), are related by the following formulas:

$$T \cdot v > 60.$$

$$Va(t) = \frac{R - r(t)}{t}; \text{ for } t = 0 \Rightarrow T, \qquad \text{Algorithm 2}$$

where r is the distance of the arm from the center of the wafer.

It can also be advantageous to regulate both the solution flow rate and the dispensing arm motion simultaneously. Moreover, when the dispensation of precursor solution is controlled as described above, the dispensation arm can be moved either centripetally, from the edge toward the center, or centrifugally, from the center of the wafer to the periphery, and still maintain the desired thickness of the precursor solution on the wafer.

3. Control of Wafer Rotation Speed During Dispensing Step.

Typically, in the preferred edge scan dispense method, the rate of rotation during the dispensing step is from about 50 to about 500 rpm, in one example, about 200 revolutions per minute (rpm) with a constant flow rate of solution onto the wafer surface. By way of example only, Example 4, FIGS. 5*a*, 5*b* and 5*c* show the results of experiments designed to determine the optimum dispense speed for dispensing a solution of HSQ in MIBK, wherein the solution flow rate was held constant. The range of film thickness (FIG. 5*a*) standard deviation FIG. 5*b*) and wafer non-uniformity (FIG. 5*c*) are minimized by using a dispense spin speed of about 200 rpm. Using similar testing methods, it is routine to determine the optimum dispense time for any desired solution of solvent and precursor.

However, it is also considered part of the invention to control the rotation speed of the wafer during the dispensing step to compensate for the differences in solution dispensation which result from the differences in linear velocity of the wafer surface at different locations radially from the wafer center. For example, if the solution flow rate and dispensing arm motion are held constant, increasing the rotation speed as the dispensing arm moves centripitally operates to maintain the linear velocity of the wafer under the dispensing arm (Algorithm 3).

$$v(t) = \frac{C}{2\pi r(t)} \qquad \text{Algorithm 3}$$

where C is a constant
and where r(t)=R−Va·t, for t=0→T.

This could result in the dispensing of a bead of solution with an even width, thereby permitting the dispensation of an even, overlapping head as the dispensing arm moves centripitally. Alternatively, if the dispensing arm is moving centrifugally, from the center of the wafer toward the edge, the wafer rotation speed can be slowed advantageously to maintain an approximately constant linear velocity of the wafer under the dispensing nozzle, thereby dispensing an even head of solution as the dispensing arm moves at constant speed.

4. Control of Solution Thickness.

The ability to provide layers of solution with different thicknesses depends upon the viscosity of the solution and the pattern of dispensation. Less viscous solutions will flow more readily, thus decreasing variations in the thickness of the dispensed solution. Conversely, more viscous solutions will tend to remain at the sites dispensed, and can therefore retain differences in solution thickness.

It is also within the scope of this invention to vary the thickness of the dispensed solution in any other desired fashion. Because the acceleration acting on the solution during the fast spin step are greater at the edges than at the middle of the wafer, it can be desirable to provide a thinner layer of solution at the center of the wafer than is dispensed at the edge of the wafer. In general, the thickness of a solution retained by a spinning wafer will depend on the distance from the center of rotation. Points on a wafer closer to the center of rotation will retain more material than points farther from the center of rotation. The amount of material lost from any particular point on a wafer also is dependent on the solution's viscosity. The higher the viscosity, the more retention at the particular site. Therefore, using the methods of this invention, it is possible to provide very even layers of spin-on solutions.

The total amount of solution needed depends upon the solution concentration, the diameter of the wafer, and the desired film thickness. In general, the minimum amount of solution is about $10^{-2}$ ml/π·cm$^2$. Thus, for a wafer with a diameter of 8 inches, about 1 ml to about 10 ml of solution typically can be used, and alternatively about 4 ml of solution, which is usually sufficient.

The dispensing step can be carried out using any other conventional processing methods. However, to control the deposition of spin-on layers more advantageously, it is preferred that the above dispensing methods be carried out within a sealed deposition chamber as described above in section I.

III. Rapid Spinning Step

A. Rapid Acceleration to High Maximum Spin Speed.

To even and thin the layer of spin-on solution, the wafers are then subjected to a fast spin step (Example 1, FIGS. 3*a* and 3*b*). In this step, the wafers are subjected to rapid acceleration, short duration of high speed rotation, and rapid deceleration. In one embodiment, a less rapid spinning (FIG. 3*a*) and lower maximum rotation speed do not provide as thin and even a thin film. In the preferred embodiments of this invention, the wafers are accelerated to their maximum spin speed rapidly, at accelerations in the range of from about $10^3$ rpm/sec to about $2.5\times10^8$ rpm/sec, alternatively from about $10^3$ rpm/sec to about $10^6$ rpm/sec, and in another example, at about $5\times10^5$ rpm/sec.

In general, the rotation speed is inversely related to the thickness of the film, with higher maximum spin speeds resulting in thinner films. The degree to which a given precursor solution is thinned during the rapid spinning step depends upon the viscosity of the solution, with more viscous solutions resulting in thicker films for a given

maximum rotation speed than for solutions with lower viscosity. The maximum spin speed should be from greater than about 500 rpm to about 12,000 rpm, in one example, from greater than about 1000 rpm to about 8000 rpm, and in another example from about 4000 rpm to about 6000 rpm. The spin step typically lasts for a time in the range of about 0.05 sec to about 3 sec, alternatively from about 0.1 sec to about 2 sec, and in another example, about 0.1 sec. After spinning, the wafers are decelerated at about the same rates as for acceleration.

We have unexpectedly found that very rapid accelerations and rapid decelerations provide more uniform film thickness than the rates of acceleration used previously. Moreover, we have unexpectedly found that the high rotation velocities permit the production of more even films. Furthermore, we have unexpectedly found that spinning wafers for a short duration at the maximum rotation speed decreases film thickness range (FIG. 6*a*), standard deviation FIG. 6*b*) and film non-uniformity (FIG. 6*c*). In fact, we found that spinning wafers for 1 second or longer increased the non-uniformity to much higher levels than using spin times of less than 1 second. Therefore, by using the combination of rapid acceleration, high rotation velocity, short duration of maximum rotation, and rapid deceleration, the reproducibility and evenness of spin-on thin films of this invention are improved.

Although the exact mechanism for this improved film quality are not known with certainty, one theory to account for the observation is that with the short duration of the spin step, there is little opportunity for the solvent to evaporate, and therefore, when the spinning is stopped, the solution flows to form a more planar configuration. Using the methods of the prior art, long spinning steps permit the partial drying of the thin film before the rapid spin step has been completed. This results in areas of partial drying which do not flow during the rotation step. Therefore, those areas of the film tend to harden in the shape attained during rotation, not a necessarily desired shape. To provide the necessary total spreading, it can be advantageous to use rotation speeds greater than typically used in the prior art. This also minimizes the time needed to spread the thin film. However, for those applications in which the evaporation of solvent is slow, such as with the use of solvents with low volatility, or in which the rate of solvent evaporation is reduced, the rotation speeds can be as low as those currently used.

Although the above theory represents a possible explanation for the results of the present invention, the success of these methods does not rely upon this or any other theory for operability. Many possible reasons may exist for the improved planarity of the thin films of the present invention, and all are considered to be part of the invention.

The spinning step can be performed at any pressure, but if highly volatile solvents are used, it is preferable to slow the rate of solvent evaporation. In one embodiment of the invention, reducing the rate of evaporation can be performed by using higher than atmospheric pressure. The use of a closed deposition system enables the manufacturer to decrease the rate of evaporation, and can result in a more uniform film thickness. Pressures range from about 1 atmosphere (atm) to about 2 atm, alternatively from about 1.5 to about 2 atm, and in another example, about 1.5 atm. Alternatively, the evaporation can be preformed in a closed system in which vapor of the solvent is introduced into the deposition chamber to decrease the rate of evaporation of solvent from the film.

Using similar procedures as described herein, it is possible to determine the optimum acceleration, maximum spin speed, and deceleration for each type of solvent, precursor, and desired film properties.

### IV. Solution Flow-In

After the rapid spinning step, the rotation of the wafer is then slowed (FIG. 3*a*) or is stopped FIG. 3*b*) for a period of time (the "solution flow-in period" or, if the rotation is zero, the "stop time") sufficient to permit even flow-in of solution across the surface of the wafer (FIG. 3*b*). In prior art spin-on methods with long spin times, there is an opportunity for the solvent to evaporate from the solution. As the solvent evaporates from the wafer during the rapid spinning step, then the final shape of the film will reflect the forces on the solution during spinning. Because during spinning, the accelerative forces are different on different parts of the wafer, the solution is subjected to different forces depending on the distance from the center of rotation. The differences in accelerative forces on different parts of a wafer can cause uneven distribution of solution over the wafer's surface. Therefore, in the prior art spin-on methods there can be a global non-planarity of the thin film.

In addition to providing more globally planar thin films, the methods of this invention permit the manufacture of semiconductor thin films with improved local planarity. Local non-uniformity occurs with respect to the pads or metal lines on a patterned wafer or semiconductor device. Using conventional spin-on methods, as the precursor solution flows over and between metal features on the wafer, there is a tendency for the solution to form a thicker layer at the centrifugal side of the metal feature compared to the centripital side of the feature (see FIG. 9). Conversely, there is a tendency for the solution to form a thinner layer over the centripital side of the feature. This local non-uniformity can result in local variations in physical and electrical properties of the thin film. Using conventional spin-on methods, the thickness of thin film at the centrifugal side of the pad can be twice or more the thickness of the film on the centripital side of the pad.

The global and local non-uniformities are at least partially overcome by the use of a flow-in step. By removing the unequal accelerative forces to which the solution is subjected in a radial direction from the wafer's center, the inclusion of a flow-in period prior to solvent evaporation increases the planarity of the solution. Thus, it is important that the precursor solution not be completely dried at the time of the flow-in step. Although a flow-in step can be used to increase the planarity of any spin-on solution, it is advantageous to also use the sealed deposition chamber, the scan dispensing methods, the rapid acceleration, short maximum spin times, and rapid deceleration of other embodiments of this invention. By using these other improvements, the planarity of the spin-on films can be increased.

The local non-uniformity of a layer on a pad or feature of a patterned wafer can be expressed as the difference in the maximum thickness minus the minimum thickness of the layer on the same pad or feature. This difference, or range, is typically greater than about 600 Å for prior art spin-on methods. However, using the methods of this invention, the local non-uniformity is generally below about 600 Å, in another example, below about 400 Å, and in yet another example, below about 300 Å.

The wafer can be rotated during flow-in if the rate of rotation is sufficiently slow as to avoid subjecting the solution to forces which would maintain an uneven distribution of the solution on the surface. However, the wafer can be stopped during the flow-in period. In general, the flow-in

period is sufficiently long to permit the thinned solution to flow in the absence of the high forces to which the solution is subjected during the rapid spin step. The flow-in period is selected depending on the physical properties of the solution used. For more viscous solutions, the flow-in period can be longer than for solutions with lower viscosity because longer periods of time permit the solution to penetrate into gaps more completely. Conversely, for solutions with lower viscosity, a shorter flow-in period can be sufficient. Additionally, the wetting behavior of the solution affects the spreading of the solution onto the wafer surface. Solutions which wet the surface more readily may require a shorter flow-in period than solutions which do not wet the surface as readily. Moreover, when the rate of solvent evaporation is reduced by increasing pressure, increasing solvent vapor pressure, or decreasing temperature, the solution flow-in period can be increased in duration.

During the flow-in period, it can be desirable to slow the rate of evaporation from the solution. Such slowing of evaporation can permit the more even flow-in of the spin-on solution. Slowing may be accomplished by selecting the pressure within the chamber, the temperature, and/or the solvent vapor pressure. In aspects of the invention in which the solvent vapor pressure and the chamber temperature are regulated, the pressure within the deposition chamber may be advantageously increased. Generally, for HSQ and MIBK, the pressures are in the range of from about 1 atmosphere (atm) to about 2 atm, in one example from about 1 atm to about 1.5 atm, and in another example about 1.5 atmosphere.

In other aspects of the invention high solvent vapor pressure is used in the chamber during the flow-in period. For certain highly volatile solvents, if the layer of solution partially dries during the rapid spinning step, the viscosity of the solution may be so high as to inhibit effective flow-in. Under these circumstances, the introduction of solvent vapor can either: 1) slow the drying of the solution, or 2) re-dissolve precursor which has already dried onto the wafer. The result of these steps is the improvement in the evenness of the spin-on layer. Typically, the solution partial pressure can be in the range of about 0% to about 99%, in one example, about 10% to about 90%, in another example, about 40% to about 60%, and in yet another example, about 20% to about 30%.

The optimum time for the flow in period can be determined for each set of deposition conditions used. Example 4 shows the results of tests comparing the film thickness range (FIG. 7*a*), standard deviation (FIG. 7*b*) and film thickness non-uniformity (FIG. 7*c*) as a function of the stop time for a solution of a spin-on film made from HSQ in MIBK. Under the conditions of these tests, a stop time of about 4 seconds produced the smallest range and standard deviation of film thickness. Unexpectedly, decreasing stop time to 2 seconds or increasing stop time to 6 seconds produced a wider range of film thicknesses, and increased the standard deviations of those thicknesses. Generally, for a HSQ/methylisobutylketone solution comprising about 10% to about 20% HSQ, the solution flow-in period at atmospheric pressure in air will typically be iu the range of about 0.5 sec to about 20 sec, alternatively from about 2 sec. to about 10 sec, and in another example, from about 5 sec to about 10 sec. For more concentrated HSQ solutions, the solution flow-in period can be greater than these times. Using similar strategies, the determination of optimum flow-in period for each type of precursor, solvent, and solution concentration can be made using methods known in the art.

V. Subsequent Processing Steps

After the deposition of the precursor solution, several steps can be carried out to: (1) remove solvents, (2) reflow the dielectric material, and (3) cure the thin film. These processes are carried out so as to achieve the final thin film with the desired properties of low dielectric constant, high dielectric strength, and high mechanical strength. These steps are typically carried out by exposing the wafer to progressively higher temperatures for each of the steps. The temperatures to which the wafer is exposed at each step depends on the solvent volatility, the melting temperature of the dielectric material, and the activation energy of the cross-linking bonds responsible for curing the thin film.

For example, if a highly volatile solvent is used, the first step of solvent evaporation can be performed at a relatively low temperature. In contrast, if a solvent of low volatility is used, the temperature is typically higher than for the solvent with high volatility. Second, if the dielectric material has a relatively low melting temperature, by way of example, poly(tetrafluoroethylene), the reflow step can be carried out a relatively lower temperature than that for a dielectric material with a higher melting temperature, by way of example only, $SiO_2$. Third, if cross-linking the thin film is desired, typically higher temperatures are advantageous to break interatomic bonds in dielectric material monomers and permit the reformation of intermolecular bonds between monomers. Thus, in general, for each solvent and spin-on material deposited, the sequence of post-deposition processing steps can be the same. However, the actual temperatures used will depend upon the physical and chemical characteristics of the solvent and spin-on material used. By way of example only, if fluorinated poly(arylene)ether (FLARE) is used as the dielectric material, the solvent evaporation temperature is typically about 150° C., the reflow temperature is about 200° C., and the curing temperature is above about 250° C.

Heating can be accomplished using resistive heaters or infrared radiation sources in the deposition chamber (FIGS. 1*a* and 1*b*), in a separate oven, or on a hot plate or other type of heater known in the art.

A. Regulation of the Rates of Solvent Evaporation.

After thin film deposition, the next step is typically to evaporate excess solvents from the film. This can be accomplished in situ, with the wafer in the deposition apparatus, either stationary or while rotating, or alternatively, the wafer can be removed from the spin apparatus and placed in a separate chamber or hot plate. Evaporation can be at reduced pressure, at atmospheric pressure, or at increased pressure. The rate of evaporation affects the uniformity of the resulting film. More rapid evaporation can result in less even film thickness and properties, while slower evaporation can result in more even thickness and reduced stress in the finished thin film. To reduce the rate of evaporation, this step can be carried out at increased pressure, at reduced temperature or in the presence of solvent vapor. The closed apparatus described above can be used advantageously to regulate the conditions during the evaporation step.

After evaporating the solvent from the wafer surface during the rapid rotation and flow in steps, most of the remaining solvent can be removed in a first baking step by exposing the wafer to elevated temperatures. The temperature desired is dependent upon the solvent to be evaporated. For evaporation times of about 1 minute, for the deposition of spin-on glass and of fluorinated poly(arylene)ethers using cyclohexanone, typical temperatures are in the range of from about 50° C. to about 250° C., in another example, from

about 100° C. to about 200° C., and in yet another example, about 150° C. For HSQ dissolved in MIBK, the typical temperature range for evaporation is from about 100° C. to about 300° C., alternatively from about 150° C. to about 250° C., and in another example, about 150° C. For BCB dissolved in mesitylene, temperatures for evaporation are in the range of about 100° C. to about 350° C., alternatively from about 160° C. to about 325° C., and in another example at about 160° C. However, it can be appreciated that the evaporation of solvents is dependent on the volatility and boiling point of the particular solvent used. Highly volatile solvents do not require temperatures as high as solvents with higher volatility.

B. Reflow of Spin-On Films.

After the solvents have been substantially evaporated, the remaining spin-on material is consolidated and evened by a reflow step, in which the wafer is subjected to temperatures above those needed for solvent evaporation. Typically, reflow is accomplished in a separate oven or a hot plate after spin-on deposition has been accomplished, but one can perform reflow steps in the deposition chamber if desired. The temperature and time of reflow is dependent on the melting and flow characteristics of the material used. Typically, for spin-on glass, HSQ and of fluorinated poly (arylene)ethers, the reflow step is carried out at temperatures in the range of from about 150° C. to about 350° C., alternatively in the range of about 150° C. to about 250° C., and in another example, about 200° C. However, it can be appreciated that for materials with lower melting temperatures, the reflow step can be carried out at lower temperatures, and for materials with higher melting temperatures, the reflow step can be carried out at higher temperatures. The time necessary can be determined using methods known in the art by measuring film characteristics after the deposition process has been completed.

C. Curing Films.

The final steps in the deposition of a spin-on dielectric layer are curing steps. The curing permits crosslinking of components of the thin film to increase the mechanical strength of the film and increases the useful lifetime of the dielectric layer. Any desired number of curing steps can be used, but we have found that it is advantageous to use at least 2 curing steps, with the second curing step being carried out at a higher temperature than the first curing step. By way of example, HSQ has a caged molecular structure having a backbone comprising alternating silicon and oxygen atoms. When deposited on a surface, the uncured film of HSQ consists of adjacent un-cross-linked HSQ molecules . However, the desired film comprises cross-linked HSQ moieties. Curing the film by creating of cross-linked HSQ molecules involves heating the layer to a temperature that can break some of the chemical bonds between atoms, typically, O—H bonds and Si—O bonds, thereby resulting in reactive moieties which can re-form with moieties of adjacent HSQ molecules, thereby cross-linking the layer. By increasing the temperature and time of the curing step, the degree of cross-linking can be increased. This cross-linking provides higher mechanical and thermal stability of the film, which result in better electrical properties and longer useful device lifetimes.

Other types of dielectric materials can be cured in similar fashions. By way of example, organic polymeric dielectric materials can contain terminal C—H and/or C—O bonds. When these types of bonds are subjected to heating, they can break, forming reactive intermediate moietics, which can react with nearby polymer chains, thereby forming cross-linking.

1. Step Curing.

In one aspect of the invention, the curing is typically performed as part of the overall post-deposition processing steps. After the reflow step, the wafer is subjected to a temperature higher than that of the reflow step. Typically, this can be accomplished by transferring the wafer from the spin deposition apparatus to a curing oven or a hot plate. For example, for HSQ, the range of curing temperatures is between about 250° C. to about 450° C., in one example, from about 300° C. to about 400° C., and in another example, about 350° C. After this first curing step, a second curing step can be carried out at a higher temperature, typically higher than about 400° C. The temperatures can be in the range of about 350° C. to about 500° C., alternatively from about 375° C. to about 450° C., and in another example, at about 400° C.

After the second curing step, a third curing step can be carried out if desired. Typically, the third temperature in the range of about 250° C. to about 450° C., alternatively about 300° C. to about 400° C., and in another example, about 350° C. Similarly, a fourth curing step can be optionally carried out. Typically, the fourth temperature in the range of about 350° C. to about 500° C., alternatively in the range of about 400° C. to about 500° C., and in another example, about 450° C.

It can be appreciated that the multi-step curing methods involve the incremental increase in temperature with each curing step.

It can also be appreciated that for other dielectric materials, the temperature advantageously used to for cross-linked films may be different. In general, the curing temperature should be sufficiently high to break some of the bonds holding the thin film together, but the temperature should not be so high as to break too many bonds. After the film is cured, it is removed from the curing oven and cooled to room temperature.

2. Combination Step-Ramp Curing In other aspects of this invention, the curing step can be accomplished according to methods described in co-pending U.S. patent application Ser. No.: 09/191,040, entitled "Hydrogen Silsesquioxane Cure Process for Manufacturing Low Dielectric Constant Interlevel Dielectric Materials" incorporated herein fully by reference This method embodies a step curing process followed by a ramp curing step, wherein the temperature is increased progressively to a maximum temperature. By way of example only, a solution of HSQ is deposited on a wafer, is dried, and then the wafer is placed in a pre-heated oven at a temperature of about 300° C. The temperature is then raised at a rate of about 3° C./min until a temperature of about 400° C. is reached. It can be appreciated that certain types of films can be advantageously cured by increasing the maximum temperature to higher than about 400° C. The temperature is then held constant for about 60 minutes, and then the temperature is lowered at a rate of about 3° C./min or less until a temperature of about 300° C. is reached, at which time, the cured wafer can be removed from the curing oven and allowed to cool to room temperature.

In general, the initial temperature is selected on the basis of routine experiments in which a dried thin film is subjected to the step increase in temperature, and the physical and/or chemical properties of the thin film are determined. Such properties include, by way of example only, the types of chemical bonds in the film, which can be determined using Fourier Transformed Infrared (STIR) Spectroscopy, measurement of film thickness, dielectric constant, dielectric strength, and mechanical strength. To carry out such a series of routine tests, a low temperature is first used, and the film

properties are determined and used to compare with the results of subsequent tests. Additional, previously uncured thin films are exposed to other, higher temperatures, and the film properties are determined. The temperature above which the film properties become undesirable then is used as the starting temperature for the combined step-ramp process. It can be appreciated that the initial temperature can be different for different types of spin-on materials.

It is also desirable to perform the curing steps in an atmosphere of an inert gas, such as nitrogen, argon, neon, helium, or other noble gas. The combination of step-ramp curing and an inert gas environment for heating, high temperature cure, and cooling steps can provide thin films with high mechanical strength and minimized oxidation, therefore leading to thin films having lower dielectric constants, such as below about 3.0.

Additionally, the determination of the desired rate of temperature increase during the ramp step can be determined using a similar strategy as described above for determining the desired initial temperature. It can be appreciated that the ramp rate can be different for different spin-on materials.

It can be appreciated that any spin-on film can be cured in this fashion in which cross-linking is desired. Moreover, it can also be appreciated that the temperature conditions can vary to suit the needs of the particular spin-on material, and the degree of cross-linking desired.

This combination method overcomes the disadvantages of the prior art curing methods in which either the temperature is raised too rapidly, thereby causing stresses in the thin film and the appearance of undesired electrical properties such as increased dielectric constant and decreased breakdown voltage, or the temperature is raised sufficiently slowly, but the total time taken to cure films is prohibitively long.

## VI. Methods of Analysis

The thickness of deposited films are determined using any device known in the art. For example, an optical method using an Optiprobe™ system (the name for an optical thin film measurement system manufactured by Thermawave) is satisfactory. Film thicknesses measured using the Optiprobe™ system are generally in the range of from greater than about 20 Å to about 20,000 Å, alternatively from about 2000 Å to about 7000 Å, and in another example, from about 4000 Å to about 5000 Å.

The dielectric constant of the deposited HSQ film is in the range of from about 2.9 to about 4.3, alternatively from about 2.9 to about 3.1, and in another example, about 2.9. The dielectric constant of other films, such as poly (tetrafluoroethylene) can be as low as about 1.9.

The global nonuniformity of layers is determined using any method known in the art. For example, using the optical method using the Optiprobe™ system, the measured non-uniformity of layer thickness on blank wafers is in the range of from less than about 0.5% to about 10%, in one example, from about 0.5% to about 5%, and in another example is about 0.5% to about 1%. For wafers with metal interconnect patterns, the global non-uniformity of the deposited layer measured using the Optiprobe™ system is less than about 20%, alternatively less than about 10%, and in another example is less than about 5%. Typically, the global non-uniformity is in the range of from about 5% to about 20%, alternatively from about 5% to about 10%, and in another example is about 5%. This degree of global non-uniformity can be achieved for patterned wafers with unequal sizes of features, such as the heights of metal lines.

Other methods for measuring film thickness and/or non-uniformity can be used, and depending on the particular method, the measured thickness and/or non-uniformity may vary. It is within the scope of this invention for any measurements of within wafer non-uniformity to be included, with the ranges of measured non-uniformity being adjusted to be equivalent to those for the Optiprobe™ system described herein.

Measurement of local non-uniformity is performed by measuring the cross-sectional thickness of a semiconductor thin film. Typically, such measurements are made using scanning electron microscopy. To measure local non-uniformity, a cross-section of thin film over a metal pad is observed, and the film thickness at least 5 points from the centripital, central, and centrifugal portions of the pad are measured. The difference between the maximum film thickness and the minimum film thicknesses are determined. This difference is hereinafter termed the local nonuniformity range. The local nonuniformity range is typically less than about 600 Å, alternatively less than about 400 Å, and in another example, less than about 300 Å. These methods are knowu in the art and are not discussed further herein.

Fourier Transformed Infrared (FTIR) Spectroscopy, determination of mechanical strength, dielectric constant, and dielectric strength are carried out by methods known in the art, and will not be described further herein.

## VII. Manufacture of Semiconductor Devices Using Spin-On Methods

After the spin-on layer has been deposited and cured, subsequent manufacture of semiconductor devices is carried out. For example, another layer of dielectric material can be deposited by chemical vapor deposition (CVD) or other methods known in the art, and subsequently planarized by chemical mechanical planarization (CMP) methods. The planarized surface of the second layer can be the substrate for additional layers of metal lines and ILD materials. By repeating the series of steps, multilayered semiconductor devices can be made.

By providing improved global and local uniformity to deposited thin films, the methods of this invention also permit the use of thinner CVD films than are required by prior art spin-on methods (see Example 5, FIG. 11). This is because there is less overall non-uniformity of patterned wafers (less than about 20%) compared to prior art methods. In contrast, the prior art methods produce films on patterned wafers with substantial global non-uniformity, being about 20% or greater of the total film thickness. With improved uniformity made possible by the methods of this invention, a thinner layer of CVD can be sufficient to fill in the low areas of the spin-on film. Furthermore, a thinner CVD film is sufficient to achieve higher global planarity than are possible using spin-on methods without the further CVD layer and CMP. With thinner CVD films, less deposition time and materials are required to deposit and planarize the CVD film. In fact, a CVD layer on the highly planar spin-on layers of this invention can be sufficiently planar to permit subsequent manufacturing steps without the necessity for a CMP step. This elimination of the need for CMP during manufacturing can further reduce the equipment cost and ILD materials needed for manufacturing semiconductor devices. Therefore, the manufacturing throughput can be increased and the total cost of semiconductor manufacture can be reduced.

The general descriptions of the methods and thin films of this invention are described further by reference to the following Examples and Figures.

## EXAMPLES

### Example 1

### Deposition of Spin-On Hydrogen Silsesquioxane Thin Films

To deposit a thin film of hydrogen silsesquioxane (HSQ), a silicon wafer was placed in a wafer cassette and subse-

quently moved to a cool plate maintained at a temperature of 23° C. The wafer was then loaded on a vacuum chuck in a spin-cup. The wafer is then rotated at 200 rpm and the solution dispense nozzle moves to about 25 mm from the edge of the wafer using equipment substantially as described in FIG. 2 above. The solution was dispensed from the nozzle as the nozzle moved centripetally toward the center of the wafer while the wafer was rotated at 200 rpm. When the nozzle reached the center of the wafer, the dispensation of the solution stopped, and at that time, the surface of the wafer was completely covered by the precursor solution.

The wafer was then rotated with an acceleration time of 0.03 seconds to a maximum rotation speed of 5000 rpm. The duration of rotation was 0.1 seconds, after which the wafer was decelerated over a time of 0.03 seconds. After the wafer stopped rotating, it was permitted to remain stopped for 4 seconds. The wafer was then rotated and edge-head removal and backside rinse steps were performed. Subsequently, the wafer was spun dry at 3000 rpm for 7 seconds. The wafer was then transferred to hot plates at 150° C., 200° C., and 350° C., for solvent hake, re-flow and hardening, respectively. Finally, the wafer was transported hack to the wafer cassette.

## Example 2

### Rapid Spin Step for Spin-On Layers

Two embodiments of the fast spin steps of the invention are graphically represented in FIGS. 3*a* and 3*b*. In one emhodiment shown in FIG. 3*a*, the wafer is rotated at ahout 400 rpm for ahout 8 sec (phase "1*a*"). The wafer is then suhjected to an increase in spin speed, with a maximum spin speed of about 3000 rpm (phase "2*a*"). After about 3 sec, the wafer spin speed is slowly reduced to about 500 rpm over ahout 3 seconds (phase "3*a*").

FIG. 3*b* shows another embodiment of the invention, showing rapid acceleration and deceleration, wherein the wafer is rotated at ahout 200 rpm for about 8 seconds during which time the solution is dispensed onto the rotating wafer (phase "1*b*"). Thereafter, the wafer is very rapidly accelerated to a maximum speed of 5000 rpm (phase "2*b*"), and shortly thereafter is rapidly stopped for a period of several seconds (the solution flow-in period or stop time; phase "3*b*"). During the stop time, the precursor solution has an opportunity to even out in the absence of high accelerative forces. After the rapid spinning step shown in FIG. 3*a*, or the stop time shown in FIG. 3*b*, the wafer can he subsequently rotated to carry out other processes known in the art, for example, evaporation of excess solvents, edge trimming and the like. In FIG. 3*b*, the subsequent rotation speed increases relatively slowly (phase "4*b*") to a steady rotation rate (phase "5*b*"). The relatively low rate of increased rotation velocity is selected to prevent the flow of the evened precursor solution hack into an uneven configuration prior to solvent evaporation.

## Example 3

### Relationship Between Deposition Variables and Film Thickness

To determine the effect of varying the time for dispensing, spin time, dispense spin speed, and stop times on film thickness and uniformity, we studied patterned wafers after edge-scan dispensing solutions of HSQ in MIBK, with a concentration of HSQ in the range of about 10% to about 20%, alternatively about 15%.

FIG. 4*a* shows the range (maximum - minimum) of film thicknesses in Å as a function of dispense time in seconds. Each data point represents measurements of thickness of the HSQ layer on the metal pads, 100 μm per side, across a single wafer. At the short dispense time of 0.9 seconds, the film thickness ranges (defined as the maximum thickness of a film minus the minimum thickness on the same wafer) varied from about 260 Å to ahout 1150 Å. At high dispense time of 1.5 sec, the range in film thickness varied from about 270 Å to about 1480 Å. In contrast, the dispense time of 1.2 sec. resulted in more even film thicknesses ranging from about 260 Å to about 600 Å. FIG. 4*b* shows the standard deviation of film thickness in Å as a function of dispense time in seconds. Each data point represents measurements from a single wafer. As with FIG. 4*a*, the dispense time of 1.2 sec. resulted in the smallest standard deviation of film thicknesses. FIG. 4*c* shows the wafer non-uniformity of film thickness as a function of the dispense time in seconds. Each data point represents measurements from a single wafer. At a dispense time of 1.2 seconds, the non-uniformity was less, heing in the range of about 2.5% to about 5%, compared to the non-uniformities ohtained at either lower or higher dispense times. At the dispense spin speed of 200 rpm, the non-uniformity was smaller than that ohtained at either slower or higher dispense spin speeds.

FIG. 5*a* shows the effect of dispense spin speed in rpm on the range (maximum —minimum) of film thickness. Each data point represents measurements from a single wafer. At a spin speed of 200 rpm, the range was smaller than at either 100 rpm or 500 rpm. FIG. 5*b* shows the standard deviation of the film thickness as a function of dispense spin speed in rpm. As with FIG. 5*a*, the dispense spin speed of 200 rpm produced the most even film thickness. FIG. 5*c* shows the non-uniformity of film thickness.

FIGS. 6*a*, 6*b* and 6*c* show film thickness range (maximum—minimum), standard deviation and film non-uniformity, respectively, as a function of spin time in seconds. Each data point represents measurements from a single wafer. At low spin times of from about 0.2 to about 0.6 sec. the range of film thickness was from about 250 Å. to ahout 650 Å. At longer spin times, the range in film thickness increased to from ahout 750 Å to ahout 1450 Å. FIG. 6*b* shows that with spin times of about 0.5 seconds and below, that the standard deviation of film thickness is minimized. Further, FIG. 6*c* shows that the wafer non-uniformity is minimized as well at spin times of about 0.5 seconds and less.

FIGS. 7*a*, 7*b* and 7*c* show the range (maximum—minimum), standard deviation and wafer non-uniformity, respectively, of film thicknesses as a function of stop time in seconds. Each data point represents measurements from a single wafer. At a stop time of 4 sec, the non-uniformity was smaller than that ohtained at either shorter or longer stop times (FIG. 7*a*). Furthermore, at stop times up to ahout 4 seconds, the non-uniformity (FIG. 7*c*) was smaller than that obtained at longer stop times.

## Example 4

### Analysis of Film Thickness and Uniformity

Examination of wafers with metal interconnect patterns onto which layers of spin-on materials were deposited using conventional methods and methods of this invention show substantial differences. The methods of this invention improves both the glohal planarity and the local planarity of the wafers.

A. Global Planarity.

FIG. **8***a* shows the results of an experiment in which patterned wafers

having diameters of 8" (200 mm) were used for the deposition of an HSQ thin films. The patterned wafers had metal pads, each of which was approximately square, with sides of 100 μm in length. We measured the thickness of the HSQ thin film using an Optiprobe™ system. The prior art method of center deposition (■) resulted in a film with a pronounced thickening at the center (site **7**). The difference in thickness between site **7** and the remainder of the wafer (average of 22.8% non-uniformity) is unacceptably high. In contrast, using the edge-scan dispensing methods of this invention, (♦) resulted in a film with no thickening at the center (site **7**). The overall non-uniformity of the thin film was 4.8%, representing an improvement of over 4 times compared to the prior art methods.

FIGS. **8***b* and **8***c* depict cross-sectional diagrams of two wafers. First, using prior methods (FIG. **8***b*), in which the solution was deposited at the center of a patterned wafer, and in which the spin times are long, the spin-on film **800** had a pronounced hump at the center. This reflects a global non-uniformity over the patterned wafer. Substrate **804** had metal lines **808** and a layer of interlayer dielectric material **812**. The interlayer dielectric material was dispensed at the centerline (CL) of the wafer and the hump of material remains at the center after spinning, and a thinner aspect of the film being present at the edge of the wafer. This hump can typically be 20% or greater of the total film thickness. In contrast, using the edge dispense method of this invention the spin-on material of wafer **802** is more even (FIG. **8***c*). There is no hump at the centerline (CL), reflecting improved global planarity.

B. Local Planarity.

Additionally, semiconductor thin films deposited using conventional spin-on and the spin-on methods of this invention show differences in local planarity. Thin films on patterned wafers were compared visually, using an microscope system. FIG. **9***a* shows a wafer **900** with a notch at the bottom edge ("notch"). Four metal pads selected for optical analysis were selected at the notch, "top", "left", and "right", as indicated. Each pad was a square pad of metal of about 100 μm on a side.

FIG. **9***b* shows 4 metal pads of a wafer coated using the center dispense standard method in which the precursor is deposited at the center of the wafer, and subsequently distributed by spinning for a relatively long spin time. The standard method produced films with non-uniform coverage, as shown by the darkened areas in the interior aspect of the wafers (FIG. **9***b*). In FIG. **9***a*, the "notch" site has an area of thickened film at the bottom, whereas the top of the pad had a thinner film. Similarly, for the "top" pad, the area of thickening was at the top, with an area of thinner film at the bottom of this pad. Moreover, for the "left" pad, the left side had a thicker film with the right side having a thinner film. Finally for the "right" pad, the right side had the thicker film, with the left side having a thinner film. However, the pad at the center of the wafer did not have such a local non-uniformity. Thus, for each pad located centrifugally from the center of the wafer, the portion of the pad located more centrifugally (toward the edge) had a thicker film whereas the portion of the pad located more centripitally had a thinner film. This local non-uniformity can become more pronounced for pads located farther from the center of rotation of the wafer.

In contrast, the edge-scan dispense method of this invention shown in FIG. **9***c* produced films with improved local non-uniformity, with a more uniform coverage, as shown by the lack of centrifugal film thickening or centripital film thinning.

The differences between prior methods and the methods of this invention are also depicted in FIG. **10***a* and **10***b*. FIG. **10***a* depicts the thin film profile of the center (C), "left" (L) and "right" (R) pads of the edge of the patterned wafer shown in FIG. **9***b*, wherein the film was deposited using prior art methods. In both cases, there as a pronounced hump at the centrifugal side (toward the edge of the wafer) of the pad and a relatively thinner film at the centripital side of the pad. In contrast, for the methods of the invention (FIG. **10***b*), the profile of the "left" and "right" pads is more uniform, with only a slight thickening at the middle of each pad, has a minimal hump, and the film is thinner in each case.

By way of example only, in an experiment to determine the local non-uniformity of a film of HSQ on a patterned wafer, we measured the range in thickness of a film on a pad, and found the maximum thickness to be 5140 Å, the minimum thickness to be 4825 Å. The difference (range) of 315 Å was substantially less than the typical local non-uniformity obtained using prior art methods.

## Example 5

### Semiconductor Devices Manufactured Using The Spin-On Methods of this Invention

FIGS. **11***a* and **11***b* depict semiconductor devices comprising the spin-on films of this invention. FIG. **11***a* depicts a single level device **1100** comprising a silicon wafer **1104** on which metal lines **1108** are deposited. A spin-on layer of interlevel dielectric (ILD) material **1112** is deposited between and over the tops of the metal lines **1108**. This layer has slight local non-uniformity. A layer of CVD deposited material **1114** is deposited on top of the spin-on layer **1112**, and the surface **1118** is planarized and polished using chemical mechanical planarization (CMP) methods.

FIG. **11***b* depicts a multilevel device **1102** manufactured with thin films of this invention. A silicon wafer **1104** has a first set of metal lines **1108** deposited thereon. A first layer of ILD spin-on material **1112** is deposited between and over the tops of the metal lines **1108**. Layer **1112** has a slight local non-uniformity. A layer of CVD deposited dielectric material **1114** is deposited on top of the first ILD layer. The surface **1115** of the second layer is planarized using CMP. A second set of metal lines **1116** is deposited on the top of the first CVD layer. A second ILD layer **1120** is deposited between and on the tops of the second set of metal lines **1116**. A second layer of CVD dielectric material **1122** is deposited, and the surface **1124** is planarized using CVD. Additional layers can be made in the same way.

While the present invention has been described with reference to its alternative embodiments and aspects, those embodiments and aspects are offered by way of example, not by way of limitation. Those of ordinary skill in the art will be enabled by this disclosure to add to or modify the embodiments of the present invention in various obvious ways. Accordingly, such modifications and additions are deemed to lie within the spirit and scope of the invention as set out in the appended claims.

## INDUSTRIAL APPLICABILITY

This invention can be used in the manufacture of thin films using spin-on deposition methods. These methods are

especially useful in the manufacture of semiconductor devices, and are specifically useful for the manufacture of semiconductor devices with narrow feature sizes. The improved methods provide for better within-wafer global and local non-uniformity and better planarization, thereby reducing the number of subsequent processing steps necessary to achieve sufficient planarity for the manufacture of semiconductor thin films. The methods permit the manufacture of high-density semiconductor devices with increased manufacturing throughput, decreased cost, and decreased environmental degradation.

What is claimed is:

**1**. A method of manufacturing a spin-on semiconductor thin film, comprising the steps of:

dispensing a solution comprising a solvent and a precursor onto the surface of a wafer;

rotating said wafer to thin and even said solution at an acceleration in the range of about $1.6\times10^5$ rpm/sec to about $2.5\times10^6$ rpm/sec; and

drying said solution, wherein the rate of solvent evaporation is decreased during at least one of the steps of dispensing, rotating and drying to even the thickness of the thin film.

**2**. The method of claim **1**, wherein the solvent is selected from the group consisting of isopropanol, naphtha and methylisobutylketone.

**3**. The method of claim **1**, wherein the rate of solvent evaporation is decreased by increasing the total pressure.

**4**. The method of claim **3**, wherein the pressure within the deposition chamber is in the range of about 1 atmosphere to about 2 atmospheres.

**5**. The method of claim **3**, wherein the pressure within the deposition chamber is in the range of about 1.5 atmospheres.

**6**. The method of claim **1**, wherein the rate of solvent evaporation is decreased by increasing the vapor pressure of said solvent.

**7**. The method of claim **6**, wherein the partial pressure of a vapor of said solvent is in the range of about 0% to about 99%.

**8**. The method of claim **6**, wherein the partial pressure of said vapor is in the range of about 10% to about 90%.

**9**. The method of claim **6**, wherein the partial pressure of said vapor is in the range of about 20% to about 30%.

**10**. The method of claim **1**, wherein the rate of solvent evaporation is decreased by decreasing the temperature.

**11**. The method of claim **10**, wherein the temperature is below about ¾ of the boiling point of said solvent in Kelvins.

**12**. The method of claim **10**, wherein the temperature is below about 60° C.

**13**. A method for manufacturing a spin-on thin film having a thickness and a dielectric constant in a sealed deposition chamber comprising the steps of:

scan dispensing a solution comprising a precursor and a solvent on a wafer in a deposition chamber;

accelerating said semiconductor wafer at a rate in the range of about $1.6\times10^5$ rpm/sec. to about $2.5\times10^8$ rpm/sec; and permitting the solvent to evaporate thereby forming a thin film, wherein the rate of evaporation of said solvent is increased.

**14**. The method of claim **13**, wherein the step of increasing the rate of evaporation of said solvent is carried out by decreasing the pressure in said deposition chamber.

**15**. The method of claim **14**, wherein said pressure in the deposition chamber is in the range of about 1 Torr to about 760 Torr.

**16**. The method of claim **13**, wherein the step of increasing the rate of evaporation of said solvent is carried out by increasing the temperature within the deposition chamber.

**17**. The method of claim **16**, wherein the temperature is in the range of about 50° C. to about 250° C.

**18**. The method of claim **16**, wherein the temperature is about 150° C.

**19**. A method for manufacturing a spin-on layer of semiconductor thin film comprising the steps of:

scan dispensing a solution of precursor on a wafer;

accelerating said semiconductor wafer at a rate in the range of about $1.6\times10^5$ rpm/sec. to about $2.5\times10^8$ rpm/sec.;

permitting the solvent on the wafer to evaporate at a first temperature; and heating the wafer at a second temperature higher than said first temperature to permit said material to reflow.

**20**. The method of claim **19**, wherein the second temperature is in the range of about 150° C. to about 350° C.

**21**. The method of claim **19**, wherein the second temperature is in the range of about 150° C. to about 250° C.

**22**. The method of claim **19**, wherein the second temperature is about 200° C.

**23**. A method for manufacturing a spin-on layer of semiconductor thin film comprising the steps of:

scan dispensing a solution of precursor on a wafer;

accelerating said semiconductor wafer at a rate in the range of about $1.6\times10^5$ rpm/sec. to about $2.5\times10^8$ rpm/sec.;

permitting the solvent on the wafer to evaporate at a first temperature;

heating the dried wafer at a second temperature higher than said first temperature to permit said material to reflow; and

heating the wafer at a third temperature higher than said second temperature to cure said thin film.

**24**. The method of claim **23**, wherein the third temperature in the range of about 250° C. to about 450° C.

**25**. The method of claim **23**, wherein said third temperature is about 350° C.

**26**. The method of claim **23**, wherein said step of heating the wafer at a third temperature is carried out in an environment containing an inert gas.

**27**. A method for manufacturing a spin-on layer of semiconductor thin film comprising the steps of:

scan dispensing a solution of precursor on a wafer;

accelerating said semiconductor wafer at a rate in the range of about $1.6\times10^5$ rpm/sec. to about $2.5\times10^8$ rpm/sec.;

permitting the solvent on the wafer to evaporate at a first temperature;

heating the dried wafer at a second temperature higher than said first temperature to permit said material to reflow;

heating the wafer at a third temperature higher than said second temperature to cure said thin film, and heating the wafer to a fourth temperature higher than said third temperature to cure said thin film.

**28**. The method of claim **27**, wherein the fourth temperature in the range of about 350° C. to about 500° C.

**29**. The method of claim **26**, wherein said fourth temperature in the range of about 400° C. to about 500° C.

**30**. The method of claim **26** wherein said third temperature is about 450° C.

**31**. The method of claim **26**, wherein said step of heating the wafer to a fourth temperature is carried out in an environment containing an inert gas.

* * * * *

EVIDENCE APPENDIX "D"

UNITED STATES PATENT AND TRADEMARK OFFICE

(3113)

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|---|---|---|---|---|
| 10/040,538 | 12/28/2001 | Stephen D. Pacetti | 50623.149 | 3811 |

7590 01/05/2007

Squire, Sanders & Dempsey L.L.P.
Suite 300
One Maritime Plaza
San Francisco, CA 94111

***FINAL OFFICE ACTION***
RESPONSE DUE: 4/5/07
NTC of APPEAL DUE: 7/5/07

| EXAMINER | |
|---|---|
| CAMERON, ERMA C | |
| ART UNIT | PAPER NUMBER |
| 1762 | |

| SHORTENED STATUTORY PERIOD OF RESPONSE | MAIL DATE | DELIVERY MODE |
|---|---|---|
| 3 MONTHS | 01/05/2007 | PAPER |

**Please find below and/or attached an Office communication concerning this application or proceeding.**

If NO period for reply is specified above, the maximum statutory period will apply and will expire 6 MONTHS from the mailing date of this communication.

DOCKETED: Final Rejection

JAN 0 9 2007

BY: DJ Attv: CK
SQUIRE, SANDERS & DEMPSEY

| Office Action Summary | Application No. | Applicant(s) | |
|---|---|---|---|
| | 10/040,538 | PACETTI ET AL. | |
| | Examiner | Art Unit | |
| | Erma Cameron | 1762 | |

*-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --*

**Period for Reply**

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

**Status**

1)☒ Responsive to communication(s) filed on *13 October 2006*.

2a)☒ This action is **FINAL**. 2b)☐ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

**Disposition of Claims**

4)☒ Claim(s) *1-7,9-26 and 33-78* is/are pending in the application.

4a) Of the above claim(s) *7,12,14,37-40,42,43,47 and 61-70* is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-6,9-11,13,15-26,33-36,41,44-46,48-60 and 71-78* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

**Application Papers**

9)☐ The specification is objected to by the Examiner.

10)☐ The drawing(s) filed on _____ is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

**Priority under 35 U.S.C. § 119**

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

**Attachment(s)**

1) ☐ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☒ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date _____.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____.
5) ☐ Notice of Informal Patent Application
6) ☐ Other: _____.

## DETAILED ACTION

### *Response to Amendment*

### *Election/Restrictions*

1. Claims 7, 12, 14, 37-40, 42-43, 47 and 61-70 are directed to an invention that is independent or distinct from the invention originally claimed for the following reasons: they are independent or distinct as discussed previously, and as acknowledged by the applicant in the 10/13/2006 response. In addition, it is a burden for the examiner to consider as many species as the applicant would like. In addition, the applicant is reminded that elections were made on 3/24/2004 and 7/02/2004 WITHOUT traverse.

Since applicant has received an action on the merits for the originally presented invention, this invention has been constructively elected by original presentation for prosecution on the merits. Accordingly, claims 7, 12, 14, 37-40, 42-43, 47 and 61-70 are withdrawn from consideration as being directed to a non-elected invention. See 37 CFR 1.142(b) and MPEP § 821.03.

### *Claim Rejections - 35 USC § 102*

2. Claims 1-6, 11, 13, 17-19, 21-24, 33-36, 44, 46, 48-54, 57-60, and 71-72 are rejected under 35 U.S.C. 102(e) as being anticipated by Castro et al. (US 6,395,326).

Examiner maintains the rejection of the previous office action for claims 1-6, 11, 13, 17-19, 21-24, 33-36, 44, 46, 48-54, 57-60 and 71-72.

### *Claim Rejections - 35 USC § 103*

3. Claims 9-10, 15-16, 20, 25-26, 41, 45, 55, 56 and 73-78 are rejected under 35 U.S.C. 103(a) as being unpatentable over Castro et al.

Examiner maintains the rejections of claims 9-10, 15-16, 20, 25-26, 41, 45, and 55-56 for the reasons outlined in the previous office action.

Examiner adds claims 73-78 to this rejection, as necessitated by amendment. The anhydrous gas of Castro would be inclusive of argon and nitrogen. The T of claim 76 is inclusive of room temperature, and the T of claim 77 is only slightly above room temperature.

4. Claims 1-6, 9-11, 13, 15-26, 33-36, 41, 44-46, 48-49, 51-58, 60 and 71-78 are rejected under 35 U.S.C. 103(a) as being unpatentable over Ding et al. (US 6,358,556) in view of You et al. (US 6,407,009).

Examiner maintains the rejection of claims 1-6, 9-11, 13, 15-26, 33-36, 41, 44-46, 48-49, 51-58, 60 and 71-72 (mistakenly written as 70-71).

Examiner adds claims 73-78 to this rejection. You teaches heated or cooled inert gases to adjust the evaporation of a coating from a substrate, depending on how volatile the solvent is (5:37-40; 7:52-8:11).

***Response to Arguments***

5. Applicant's arguments filed 10/13/2006 have been fully considered but they are not persuasive.

Castro:

The applicant has argued that Castro does not teach heated gas. The examiner disagrees. Castro teaches air pressure to deliver the coating, including bursts of air pressure (9:26-37), and also teaches a heating assembly 52 with a heating nozzle 56 to control the drying of the coating (11:11-53).

Ding and You:

The applicant has argued that Ding fails to teach directing a gas onto the stent. The examiner disagrees. Ding teaches coating a stent using an air brush device (3:47-58). The applicant has also argued that there is no motivation to combine Ding and You. The motivation to combine is to add the controlled drying aspects of the You invention to the Ding process, not

to "correct" conformity of the Ding coating. The applicant has also argued that the two references teach away from each other. The examiner disagrees in that only certain aspects of the You process (that is, the control of the drying by adjusting the T of the gas blown onto the coating, depending on the volatility of the solvent being used) are being added to the Ding process, and the fact that Ding has open lattice work and You does not is immaterial to the combination. The applicant has also argued that You only teaches the application of a cooled gas to inhibit the solvent evaporation. The examiner strongly disagrees. You teaches either cooling the gas or heating the gas , depending on the volatility of the solvent being used (7:52-8:11) (8:5-7: "Conversely, for solvents which are not as volatile as naphtha or methylisobutylketone, a higher temperature in the chamber can be advantageously used without an undesirably high rate of evaporation.").

***Declarations under 37 CFR 1.132***

6. The Declarations under 37 CFR 1.132 filed 10/13/2006 is insufficient to overcome the rejection of claims 1-6, 9-11, 13, 15-26, 33-36, 41, 44-46, 48-60 and 71-78 based upon 6395326 as set forth in the last Office action because: the declarations offer no substantive reasons for their statements that 6395326 does not teach each of the independent claims, and are merely opinion.

***Conclusion***

7. Applicant's amendment necessitated the new ground(s) of rejection presented in this Office action. Accordingly, **THIS ACTION IS MADE FINAL**. See MPEP § 706.07(a). Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for reply to this final action is set to expire THREE MONTHS from the mailing date of this action. In the event a first reply is filed within TWO MONTHS of the mailing date of this final action and the advisory action is not mailed until after the end of the THREE-MONTH shortened statutory period, then the shortened statutory period will expire on the date the advisory action is mailed, and any extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of the advisory action. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the date of this final action.

8. Any inquiry concerning this communication or earlier communications from the examiner should be directed to Erma Cameron whose telephone number is 571-272-1416. The examiner can normally be reached Monday-Friday.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Timothy Meeks can be reached on 571-272-1423. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

Erma Cameron

ERMA CAMERON
PRIMARY EXAMINER

Erma Cameron
Primary Examiner
Art Unit 1762
December 31, 2006

FORM PTO-1449 (Modified) US DEPARTMENT OF COMMERCE
US Patent and Trademark Office

# INFORMATION DISCLOSURE CITATION in an Application

(Use several sheets if necessary)



| Docket No. | Application No. |
|---|---|
| 50623.149 | 10/040,538 |
| Applicant: Pacetti et al. | |
| Filing Date: December 28, 2001 | Group Art Unit: 1762 |

## U.S. PATENT DOCUMENTS

| Examiner Initial | Ref. No. | Document Number | Date of Patent | Name | Class | Subclass | Filing Date If Appropriate |
|---|---|---|---|---|---|---|---|
| ECC | A1 | 6,818,247 | 11/16/04 | Chen et al. | | | |
| | A2 | | | | | | |
| | A3 | | | | | | |
| | A4 | | | | | | |
| | A5 | | | | | | |
| | A6 | | | | | | |

## FOREIGN PATENT DOCUMENTS

| Examiner Initial | Ref. No. | Document Number | Date of Publication | Country | Class | Subclass | Translation Yes | Translation No |
|---|---|---|---|---|---|---|---|---|
| | B1 | | | | | | | |
| | B2 | | | | | | | |
| | B3 | | | | | | | |
| | B4 | | | | | | | |
| | B5 | | | | | | | |
| | B6 | | | | | | | |
| | B7 | | | | | | | |
| | B8 | | | | | | | |
| | B9 | | | | | | | |
| | B10 | | | | | | | |

## OTHER DOCUMENTS (Including Author, Title, Date, Pertinent Pages etc.)

| | |
|---|---|
| | C1 |
| | C2 |
| | C3 |
| | C4 |
| | C5 |
| | C6 |
| | C7 |
| | C8 |

EXAMINER /Erma Cameron/ DATE CONSIDERED 12/16/2006

EVIDENCE APPENDIX "E"

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|---|---|---|---|---|
| 10/040,538 | 12/28/2001 | Stephen D. Pacetti | 50623.149 | 3811 |

7590 04/19/2006

Squire, Sanders & Dempsey L.L.P.
Suite 300
One Maritime Plaza
San Francisco, CA 94111

DOCKETED: due 7/19/06

APR 25 2006

BY: TAB Atty: ML

SQUIRE, SANDERS & DEMPSEY

| EXAMINER | |
|---|---|
| MICHENER, JENNIFER KOLB | |
| ART UNIT | PAPER NUMBER |
| 1762 | |

DATE MAILED: 04/19/2006

Please find below and/or attached an Office communication concerning this application or proceeding.

| Office Action Summary | Application No. | Applicant(s) | |
|---|---|---|---|
| | 10/040,538 | PACETTI ET AL. | |
| | Examiner | Art Unit | |
| | Jennifer K. Michener | 1762 | |

*-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --*

**Period for Reply**

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

**Status**

1)☒ Responsive to communication(s) filed on *1/31/2006*.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

**Disposition of Claims**

4)☒ Claim(s) *1-7,9-11,13,15-26,33-70* is/are pending in the application.

4a) Of the above claim(s) *7,37-40,42,43,47 and 61-70* is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-6,9-11,13,15-26,33-36,41,44-46 and 48-60* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

**Application Papers**

9)☐ The specification is objected to by the Examiner.

10)☐ The drawing(s) filed on _____ is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

**Priority under 35 U.S.C. § 119**

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

**Attachment(s)**

1) ☐ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☐ Information Disclosure Statement(s) (PTO-1449 or PTO/SB/08) Paper No(s)/Mail Date _____.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____.
5) ☐ Notice of Informal Patent Application (PTO-152)
6) ☐ Other: _____.

## DETAILED ACTION

### *Election/Restrictions*

1. Based on Applicant's amendments and arguments, claims 54-70 are rejoined with the elected group of the restriction requirement. Claims 61-70, however, are directed to the non-elected species and are withdrawn from consideration along with claims 37-40, 42-43, and 47.

2. Claims 7, 37-40, 42-43, 47, and 61-70 are withdrawn from consideration as being directed to a non-elected invention. See 37 CFR 1.142(b) and MPEP § 821.03.

3. Claims 1-6, 9-11, 13, 15-26, 33-36, 41, 44-46, and 48-60 are examined below.

### *Claim Rejections - 35 USC § 112*

4. The rejection of claims 13, 16, 23-26, 33, 44-46, 48-53 under 35 U.S.C. 112, first paragraph, has been withdrawn.

5. The rejection of "directly" in claims 13, 16, 23-26, 33, 44-46, 48-53 under 35 U.S.C. 112, second paragraph, has been withdrawn, based on Applicant's clarification of arguments.

Examiner has interpreted the term "directly" given its broadest reasonable interpretation, despite the arguments of 3/30/05.

### *Claim Rejections - 35 USC § 102*

6. Claims 1-6, 11, 13, 17-19, 21-24, 33-36, 44, 46, 48-54, 57-60, and 71-72 are rejected under 35 U.S.C. 102(e) as being anticipated by Castro et al. (US 6,395,326).

Examiner maintains the rejection of the previous office action for claims 1-6, 11, 13, 17-19, 21-24, 33-36, 44, 46, and 48-53.

As necessitated by amendment, claim 54 is added to this rejection for the same reasons as applied to claims 23, 33, 34, 44 and 51. Claims 57, 58, 59, and 60 are added to this rejection for the same reasons as applied to claims 46, 49, 50, and 48, respectively. Claims 71-72 are added to this rejection because Castro's nozzle is capable of directing heat to discrete areas of the stent, with care taken not to actually touch the stent, requiring pointing the nozzle at the stent, but at least at some distance.

### *Claim Rejections - 35 USC § 103*

7. Claims 9-10, 15-16, 20, 25-26, 41, 45, 55, and 56 are rejected under 35 U.S.C. 103(a) as being unpatentable over Castro et al.

Examiner maintains the rejections of claims 9-10, 15-16, 20, 25-26, 41, and 45 for the reasons outlined in the previous office action.

Examiner adds claims 55 and 56 to this rejection, as necessitated by amendment, for the same reasons as applied to claims 41 and 45.

8. Claims 1-6, 9-11, 13, 15-26, 33-36, 41, 44-46, 48-49, 51-58, 60, and 70-71 are rejected under 35 U.S.C. 103(a) as being unpatentable over Ding et al. (US 6,358,556) in view of You et al. (US 6,407,009).

Examiner maintains the rejection of claims 1-6, 9-11, 13, 15-26, 33-36, 41, 44-46, 48-49, 51-53.

Examiner adds claims 54-58 and 60 to this rejection for the reasons applied to claims 23, 33, 34, 44, 51, 41, 45, 46, 49, and 48.

Examiner adds claims 70-71 to this rejection because You teaches altering the temperature by providing bias gas from 126 via a gas inflow source 124 and out through the solvent injector 130. The outlet appears to be pointed at the substrate to be coated on the chuck 104 (see also, col. 5, line 65-col. 6, line 6).

***Response to Arguments***

9. Applicant's arguments filed 1/31/2006 have been fully considered but they are not persuasive.

Applicant argues that Examiner is speculating that Castro teaches blowing of gas and that Applicant's speculation that a glowing pin is used, instead of gas, is much more reasonable. Applicant argues that the conduit of Castro could be used for housing electrical wires, etc.; that the materials of Castro (metal, glass, high-temperature plastics) are more likely to be used with heating pins than gas blowers; and that it is difficult to regulate the flow of gas onto the discrete areas of Castro.

Examiner disagrees.

One of ordinary skill in the art, upon reading Castro, would immediately envision the use of heated gas. Castro teaches delivering heat from a heating control system to a heating nozzle via heat conduit.

The use of a glowing pin is not possible in the method of Castro. A glowing pin stuck into the nozzle of Castro runs counter to Castro's teachings. Castro teaches delivering heat from a heating control system to a heating nozzle via a conduit. The local heat provided by the glowing pin scenario of Applicant does not travel from a control system to a nozzle via a conduit. The conduit of Castro is not for housing electrical wires, but, rather, for conveying heat from the control system to the nozzle. Examiner also disagrees with Applicant's bold statement that metal, glass or high-temperature plastics would be more likely used with heating pins than gas blowers. Gas blowers such as hair dryers and leaf blowers are made of metal, glass, or high-temperature plastics. Additionally, Castro teaches the use of an "orifice" for application of heat. This orifice may be smaller or larger depending on the type of coverage desired. The orifice, or opening, of Castro would not be an opening if it were plugged with a glowing pin. Further, Castro does not merely teach heating discrete areas, which Applicant believes warrants the use of glowing pins. When reading that passage in context, Castro teaches the use of larger orifices for heating the entire surface of the prosthesis and smaller orifices for heating discrete areas. The smaller-sized orifice taught by Castro would be capable of regulating a discrete flow of gas.

Examiner further notes that the hollow conduit of Castro inherently contains a gas. It is taught that heat is provided via that conduit. When heat is applied to gas, gas expands

and, in this case, would expand and exit via the nozzle of Castro onto the substrate of Castro, as required by the claim.

The use of a heated gas in the method of Castro is inherent.

Applicant takes issue with Examiner's argument regarding warm gas vs. liquid and argues that the absence of liquid does not require the use of gas.

Examiner apologizes for any confusion, however, maintains that her reasoning is valid. Castro teaches heat traveling from a heat system via a conduit, out a nozzle. Conduits in general, and Castro's in specific, convey fluid substances. A fluid is either a liquid or gas. Examiner's point is that since Castro conveys a fluid and that fluid is not a liquid, it is inherently a gas.

Applicant argues that Examiner has disregarded the claim limitation directed to selecting a gas temperature based on the solvent vapor pressure in regards to Castro.

Examiner disagrees.

As outlined by Examiner Jolley, dimethylacetamide has a vapor pressure of less than 17.54 and Castro uses heating to induce evaporation, as claimed.

Applicant argues that gas is not directed to the substrate in You.

This limitation is addressed above.

Applicant asserts that Examiner is "making up the fact" that Ding is concerned with conformal or uniform coatings as Ding fails to even remotely discuss problems associated with application of coating to stents, such as cob-web formation between struts, etc.

Examiner disagrees.

Ding teaches in column 3, lines 16 and 53-57 that his coating process enables a thin layer of coating material to "adherently conform to and cover the entire surface of the filaments of the open structure of the stent but in a manner such that the open lattice nature of the structure of the braid or other pattern is preserved in the coated device" (emphasis added).

You teaches the desirability of creating thin, even coatings without pooling, and is combinable with Ding for the reasons of the previous office actions.

## *Conclusion*

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Jennifer K. Michener whose telephone number is (571) 272-1424. The examiner can normally be reached Monday-Wednesday.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Timothy H. Meeks can be reached on 571-272-1423. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

Jennifer K. Michener
Primary Examiner
Art Unit 1762
April 17, 2006

jkm

EVIDENCE APPENDIX "F"

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|---|---|---|---|---|
| 10/040,538 | 12/28/2001 | Stephen D. Pacetti | 50623.149 | 3811 |

7590 09/30/2004

Squire, Sanders & Dempsey L.L.P.
Suite 300
One Maritime Plaza
San Francisco, CA 94111

| EXAMINER | |
|---|---|
| JOLLEY, KIRSTEN | |

| ART UNIT | PAPER NUMBER |
|---|---|
| 1762 | |

DATE MAILED: 09/30/2004

Please find below and/or attached an Office communication concerning this application or proceeding.

DATES ENTERED Response due 12/30/04

OCT 0 4 2004

BY CALENDARED
ATTORNEY
SQUIRE, SANDERS & DEMPSEY

PTO-90C (Rev. 10/03)

| Office Action Summary | Application No. | Applicant(s) | |
|---|---|---|---|
| | 10/040,538 | PACETTI ET AL. | |
| | Examiner | Art Unit | |
| | Kirsten C Jolley | 1762 | |

*-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --*

**Period for Reply**

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

**Status**

1)☒ Responsive to communication(s) filed on *02 July 2004*.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

**Disposition of Claims**

4)☒ Claim(s) *1-32* is/are pending in the application.

4a) Of the above claim(s) *8,12,14 and 27-32* is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-7,9-11,13 and 15-26* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

**Application Papers**

9)☐ The specification is objected to by the Examiner.

10)☐ The drawing(s) filed on _____ is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

**Priority under 35 U.S.C. § 119**

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

**Attachment(s)**

1) ☒ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☒ Information Disclosure Statement(s) (PTO-1449 or PTO/SB/08) Paper No(s)/Mail Date *6/6/02*.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____.
5) ☐ Notice of Informal Patent Application (PTO-152)
6) ☐ Other: _____.

## DETAILED ACTION

### *Election/Restrictions*

1. Applicant's election without traverse of Group I in the reply filed on July 2, 2004 is acknowledged. Claims 8 and 27-32 are withdrawn from further consideration pursuant to 37 CFR 1.142(b) as being drawn to nonelected device and apparatus.

2. Claims 12 and 14 are withdrawn from further consideration pursuant to 37 CFR 1.142(b) as being drawn to a nonelected species, there being no allowable generic or linking claim. Election was made without traverse in the reply filed on July 2, 2004.

### *Claim Rejections - 35 USC § 102*

3. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless –
>
> (e) the invention was described in (1) an application for patent, published under section 122(b), by another filed in the United States before the invention by the applicant for patent or (2) a patent granted on an application for patent by another filed in the United States before the invention by the applicant for patent, except that an international application filed under the treaty defined in section 351(a) shall have the effects for purposes of this subsection of an application filed in the United States only if the international application designated the United States and was published under Article 21(2) of such treaty in the English language.

4. Claims 1-7, 11, 13, and 17-19, and 21-24 are rejected under 35 U.S.C. 102(e) as being anticipated by Castro et al. (US 6,395,326).

Castro et al. discloses a method of coating implantable, expandable stents with a coating composition comprising a solvent, polymer, and active agent. Castro et al. discloses that dimethylacetamide may be used as the solvent in its coating composition (col. 13, lines 1-10).

Dimethylacetamide is not considered volatile according to the invention and has a vapor pressure of less than 17.54 Torr (1.5 Torr at 20 C). Castro et al. teaches coating the stents by using a dispenser having a nozzle through which composition is delivered, which meets the limitation of spraying. Castro et al. also teaches that a heating assembly 52 is used for controlled drying of the coating (col. 11). Heating assembly 52 comprises heating nozzle 56 which directs heated air at the coated stent to induce evaporation of the solvent, as disclosed in col. 18, lines 1-12.

As to claim 5, Castro et al. discloses that the polymer in the coating solution may be ethylene vinyl alcohol copolymer (col. 12, line 63), and the solvent may be dimethylacetamide as discussed above.

As to claim 6, Castro et al. teaches use of paclitaxel or docetaxel as the active agent in the coating solution in col. 14, lines 1-2.

As to claim 7, Castro et al. teaches that multiple layers may be applied at col. 19, lines 4-8.

As to claims 17-18, the stent of Castro et al. is rotated and moved linearly along its axis during delivery of the coating solution to the device because a stent is cylindrical and longitudinal and because Castro et al. teaches that the delivery device may be stationary while the stent moves thereunder (col. 16, lines 1-11).

As to claim 19, Castro et al. teaches that the stent may be expanded during deposition (col. 7, line 53).

As to claim 22, it is noted that the temperature of the implantable device will necessarily be increased (above atmospheric temperature) at least a little bit during the heating/drying of the coating composition.

With respect to claims 3 and 23-24 which require directing gas simultaneous with applying the coating composition, it is noted that Castro et al. teaches that delivery of the composition may be applied using air pressure (col. 9, lines 28-35). Air pressure acting upon a coating solution comprising solvent necessarily induces evaporation of the solvent. Likewise, the temperature of the air used to apply air pressure will inherently be adjusted to induce evaporation of the solvent.

### *Claim Rejections - 35 USC § 103*

5. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

6. This application currently names joint inventors. In considering patentability of the claims under 35 U.S.C. 103(a), the examiner presumes that the subject matter of the various claims was commonly owned at the time any inventions covered therein were made absent any evidence to the contrary. Applicant is advised of the obligation under 37 CFR 1.56 to point out the inventor and invention dates of each claim that was not commonly owned at the time a later invention was made in order for the examiner to consider the applicability of 35 U.S.C. 103(c) and potential 35 U.S.C. 102(e), (f) or (g) prior art under 35 U.S.C. 103(a).

7. Claims 9-10, 15-16, 20, and 25-26 are rejected under 35 U.S.C. 103(a) as being unpatentable over Castro et al.

Castro et al. is applied for the reasons discussed above in section 4.

As to claims 9-10, Castro et al. teaches that nozzle 26 is positioned over or in contact with strut 68 of the stent (col. 16, lines 50-51). Castro et al. is silent with regard to the exact distance above the stent, or the flow rate of coating material applied to the stent. With respect to claim 15, Castro et al. is also silent with regard to the flow rate of the heating air applied to dry the coating. These are all result-effective variables depending upon the particular coating solution used, the size and shape of the stent being coated, the desired thickness of the coating, etc. It is well settled that determination of optimum values of cause effective variables such as these process parameters is within the skill of one practicing in the art. *In re Boesch*, 205 USPQ 215 (CCPA 1980). As to claim 16, it is well known to add radiopaque elements, such as gold elements, to bioactive compositions for coating stents. It would have been obvious for one having ordinary skill in the art to have added a radiopaque element to Castro et al.'s coating compositions because Castro et al. broadly teaches that any bioactive/therapeutic agents which are currently available are equally applicable for use with its invention.

As to claim 20, Castro et al. teaches that the heating may be conducted in an anhydrous atmosphere. It would have been obvious for one having ordinary skill in the art to have used inert gas as the heating gas upon seeing this teaching because inert gases are anhydrous.

As to claim 25, Castro et al. is silent with regard to the temperature of the gas used for applying air pressure. It would have been obvious to have used a gas at room temperature (25 C) in the absence of a teaching of a particular temperature since it would be most economical and efficient to use room temperature air. It is noted that claim 26 is broad enough to read on use of a gas that is only slightly above ambient temperature. This is not a patentable variation over

using room temperature air. It is noted that air would necessarily be heated slightly during the process of being conveyed through the dispenser tubing and nozzle.

8. Claims 1-7, 9-11, 13, and 15-26 are rejected under 35 U.S.C. 103(a) as being unpatentable over Ding et al. (US 6,358,556) in view of You et al. (US 6,407,009).

Ding et al. discloses a method of coating implantable stents with a thin layer of a coating composition comprising a solvent, polymer, and active agent (see Abstract and col. 3, lines 29-33). Ding et al. discloses coating by spraying the composition on a rotating stent, using an evaporative solvent that has a high vapor pressure/is volatile to produce a desired viscosity and layer thickness (col. 3, lines 48-53). Ding et al. discloses using a solvent of tetrahydrofuran (THF) in its Examples; THF has a vapor pressure greater than 17.54 Torr at ambient temperature (129 Torr at 20 C). Ding et al. teaches using an air brush to apply the coating, therefore Ding et al. teaches directing a gas onto the implantable device. However, Ding et al. lacks a teaching of directing a gas on to the implantable device whereby the temperature of the gas is adjusted to inhibit the evaporation of the solvent.

It is very well known in the coating art to control the evaporation of solvent from a coating material (either to speed up evaporation or slow down evaporation) by adjusting the temperature of the atmosphere surrounding the coating. You et al. is cited as an exemplary teaching of such a concept (col. 5, line 37 to col. 6, line 6; col. 6, line 40 to col. 7, line 8; and col. 7, line 53 to col. 8, line 10). You et al. is directed to method of coating with resist liquids which comprise polymer in volatile solvent, and teaches that if solvent evaporation rates are too high then the deposited material can crack. You et al. teaches that, in order to control and slow the

rate of evaporation, the temperature inside a deposition chamber can be decreased during deposition. One means for cooling is via cold air, for example using cooled inert bias gas (col. 5, line 63 to col. 6, line 6). It would have been obvious to have incorporated the teachings of You et al. into the process of Ding et al. by performing coating in a deposition chamber which is cooled using cool air or inert gas to control the evaporation of the high vapor pressure solvent in the method of Ding et al. in order to ensure that the deposited coating does not crack due to too rapid evaporation, particularly since such a method of controlling evaporation using atmospheric temperature is well known in the coating art. One skilled in the art would have expected successful results since both references are similarly related to the deposition of polymeric coatings in a volatile solvent on a rotating substrate.

As to claim 5, Ding et al. generally discloses that "thermoplastic elastomers in general" may be used as the polymeric material in its coating compositions (col. 4, line 59). It would have been obvious to one having ordinary skill in the art to have selected a specific thermoplastic elastomer, such as ethylene vinyl alcohol copolymer, from the broad class taught by Ding et al. because a specific member of the broad class would be expected to function in a similar and successful manner of providing hydrophobic biostable elastomeric coating properties to a stent. Further it would have been obvious to have substituted one solvent for another with the expectation of equivalent results since the solvent merely evaporates from the coating after application.

As to claim 6, Ding et al. generally teaches the use of antibiotics as the biologically active species in the composition of his invention (col. 5, line 2). While Ding et al. does not specifically teach the use of actinomycin D as the bioactive agent, it is noted that actinomycin D

is an antibiotic agent well-known in the medical coating art. It would have been obvious to one having ordinary skill in the art to have selected a specific antibiotic, such as actinomycin D, from the broad class of antibiotics taught by Ding et al. because a specific member of the broad class would be expected to function in a similar and successful manner of providing antibiotic properties to a stent.

As to claim 7, Ding et al. teaches applying multiple layers by spraying at col. 11, lines 7-11.

As to claims 9-10, Ding et al. is silent with regard to the distance from the tip of the sprayer to the substrate and the flow rate of coating material. These are known result-effective variables depending upon the desired thickness, viscosity of coating material, exact type of sprayer used, etc. It is well settled that determination of optimum values of cause effective variables such as these process parameters is within the skill of one practicing in the art. *In re Boesch*, 205 USPQ 215 (CCPA 1980).

As to claim 13, it is noted that the flow of chilled air in a deposition chamber, as in the process of Ding et al. in view of You et al., would necessarily comprise air/gas which flows at an angle relative to the direction of the spray. As to claim 15, the flow rate of the chilled air/gas would be determined through routine experimentation depending upon the degree of cooling needed. As to claim 16, it is well known to add radiopaque elements, such as gold elements, to bioactive compositions for coating stents. It would have been obvious for one having ordinary skill in the art to have added a radiopaque element to Ding et al.'s coating compositions because Ding et al. is specifically not limiting as to the bioactive agents which may be used in its invention.

As to claim 22, it is noted that the temperature of the implantable device will necessarily be decreased (lower than atmospheric temperature) as well as the coating material since it is located in a chamber of chilled air/gas.

As to claim 25, the temperature of the chilled air/gas is necessarily lower than 25 C since it is "chilled."

***Conclusion***

9. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure. Hossainy et al. (US 6,153,252) similarly teaches a process of coating a stent with a coating solution comprising dimethylacetamide as the solvent.

10. Any inquiry concerning this communication or earlier communications from the examiner should be directed to Kirsten C Jolley whose telephone number is 571-272-1421. The examiner can normally be reached on Monday to Thursday and every other Friday.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Shrive P Beck can be reached on 571-272-1415. The fax phone number for the organization where this application or proceeding is assigned is 703-872-9306.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

Kirsten C Jolley
Patent Examiner
Art Unit 1762

kcj

INFORMATION DISCLOSURE CITATION IN AN APPLICATION

(Use several sheets if necessary)

FORM PTO 1449 (modified)

| DOCKET NUMBER | APPLICATION NUMBER |
|---|---|
| 50623.149 | 10/040,538 |
| APPLICANTS: Stephen D. Pacetti et al. | |
| FILING DATE: December 28, 2001 | |
| EXAMINER: Unassigned | GROUP ART UNIT: 1762 |

U.S. PATENT DOCUMENTS

| *EXAMINER INITIAL | REF | DOCUMENT NUMBER | DATE | NAME | CLASS | SUB CLASS | FILING DATE IF APPROPRIATE |
|---|---|---|---|---|---|---|---|
| KCJ | A | 4,733,665 | 3/29/88 | Palmaz | 128 | 343 | |
| KCJ | B | 4,800,882 | 1/31/89 | Gianturco | 128 | 343 | |
| KCJ | C | 4,886,062 | 12/12/89 | Wiktor | 128 | 343 | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

COPY OF PAPERS ORIGINALLY FILED

FOREIGN PATENT DOCUMENTS

| | | DOCUMENT NUMBER | DATE | COUNTRY | CLASS | SUB CLASS | TRANSLATION YES | NO |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

OTHER DOCUMENTS (*Including Author, Title, Date, Pertinent Pages, Etc.*)

| | | |
|---|---|---|
| | | |
| | | |
| | | |

RECEIVED JUN 11 2002 TC 1700

EXAMINER Kirsten C Jolley | DATE CONSIDERED 9/27/04

EXAMINER: Initial if citation considered, whether or not citation is in conformance with MPEP Section 609; Draw line through citation if not information and not considered. Include copy of this with next communication to applicant.

| Notice of References Cited | Application/Control No. 10/040,538 | Applicant(s)/Patent Under Reexamination PACETTI ET AL. | |
|---|---|---|---|
| | Examiner Kirsten C Jolley | Art Unit 1762 | Page 1 of 1 |

**U.S. PATENT DOCUMENTS**

| * | | Document Number Country Code-Number-Kind Code | Date MM-YYYY | Name | Classification |
|---|---|---|---|---|---|
| | A | US-6,395,326 | 05-2002 | Castro et al. | 427/2.24 |
| | B | US-6,407,009 | 06-2002 | You et al. | 438/782 |
| | C | US-6,358,556 | 03-2002 | Ding et al. | 427/2.24 |
| | D | US-6,153,252 | 11-2000 | Hossainy et al. | 427/2.3 |
| | E | US- | | | |
| | F | US- | | | |
| | G | US- | | | |
| | H | US- | | | |
| | I | US- | | | |
| | J | US- | | | |
| | K | US- | | | |
| | L | US- | | | |
| | M | US- | | | |

**FOREIGN PATENT DOCUMENTS**

| * | | Document Number Country Code-Number-Kind Code | Date MM-YYYY | Country | Name | Classification |
|---|---|---|---|---|---|---|
| | N | | | | | |
| | O | | | | | |
| | P | | | | | |
| | Q | | | | | |
| | R | | | | | |
| | S | | | | | |
| | T | | | | | |

**NON-PATENT DOCUMENTS**

| * | | Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages) |
|---|---|---|
| | U | |
| | V | |
| | W | |
| | X | |

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

EVIDENCE APPENDIX "G"

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|---|---|---|---|---|
| 10/040,538 | 12/28/2001 | Stephen D. Pacetti | 50623.149 | 3811 |

7590 07/05/2005

Squire, Sanders & Dempsey L.L.P.
Suite 300
One Maritime Plaza
San Francisco, CA 94111

| EXAMINER | |
|---|---|
| MICHENER, JENNIFER KOLB | |

| ART UNIT | PAPER NUMBER |
|---|---|
| 1762 | |

DATE MAILED: 07/05/2005

Please find below and/or attached an Office communication concerning this application or proceeding.

**FINAL REJECTION**

2-MONTH RESPONSE DUE: 9/5/05
3-MONTH RESPONSE DUE: 10/5/05
NOTICE OF APPEAL DUE: 1/5/2006
(6-MONTH PERIOD ENDS): 1/5/2006

DATES ENTERED Response Due 10/5/05

JUL 07 2005

BY ATTORNEY MP CALENDARED PM
SQUIRE, SANDERS & DEMPSEY

| Office Action Summary | Application No. | Applicant(s) | |
|---|---|---|---|
| | 10/040,538 | PACETTI ET AL. | |
| | Examiner | Art Unit | |
| | Jennifer K. Michener | 1762 | |

*-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --*

**Period for Reply**

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for raply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified abova, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing data of this communication.
- Failure to reply within the set or extended period for raply will, by statute, cause tha application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent tarm adjustment. Sea 37 CFR 1.704(b).

**Status**

1)☒ Responsive to communication(s) filed on *30 March 2005*.

2a)☒ This action is **FINAL**. 2b)☐ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

**Disposition of Claims**

4)☒ Claim(s) *1-7,9-26 and 33-70* is/are pending in the application.

4a) Of the above claim(s) *7,12,14,37-40,42,43,47 and 54-70* is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-6,9-11,13,15-26,33-36,41,44-46 and 48-53* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

**Application Papers**

9)☐ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on *28 December 2001* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

**Priority under 35 U.S.C. § 119**

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

**Attachment(s)**

1) ☐ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☒ Information Disclosure Statement(s) (PTO-1449 or PTO/SB/08) Paper No(s)/Mail Date *4/8/2005*.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____.
5) ☐ Notice of Informal Patent Application (PTO-152)
6) ☐ Other: _____.

## DETAILED ACTION

### *Election/Restrictions*

1. Newly submitted claims 54-70 are directed to an invention that is independent or distinct from the invention originally claimed for the following reasons: original claims are directed to the use of temperature to either inhibit or induce evaporation of solvent from a coating based on the volatility of the solvent. New claims are devoid of these limitations. Furthermore, new claims require the use of a holding fixture.

2. Newly submitted claims 37-40, 42-43, and 47 are directed to an invention that is independent or distinct from the invention originally claimed for the following reasons: examined claims (such as claim 3) were directed to the simultaneous application of composition and gas. The newly-added claims require termination of spraying composition prior to directing the gas or require the spraying and directing to occur in sequence. Simultaneous application and sequential application are distinct species. The new claims even differ from the original form of claim 7 which required only the repetition of applying and directing (but not that applying and directing occur sequentially). Claim 7 has been modified to embody the second species.

Since applicant has received an action on the merits for the originally presented invention and species, this invention has been constructively elected by original presentation for prosecution on the merits. Accordingly, claims 7, 37-40, 42-43, 47, and 54-70 are withdrawn from consideration as being directed to a non-elected invention. See 37 CFR 1.142(b) and MPEP § 821.03.

*As necessitated by amendment, the following new 112 rejections are presented:*

***Claim Rejections - 35 USC § 112***

3. The following is a quotation of the first paragraph of 35 U.S.C. 112:

> The specification shall contain a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same and shall set forth the best mode contemplated by the inventor of carrying out his invention.

4. Claims 13, 16, 23-26, 33, 44-46, 48-53 are rejected under 35 U.S.C. 112, first paragraph, as failing to comply with the written description requirement. The claim(s) contains subject matter which was not described in the specification in such a way as to reasonably convey to one skilled in the relevant art that the inventor(s), at the time the application was filed, had possession of the claimed invention. Examiner is unable to find reference to "directly" blowing a gas onto the device. Examiner finds reference to "directing a gas onto" the device, however, Applicant appears to draw a distinction between these two limitations for the purposes of his amendment.

5. The following is a quotation of the second paragraph of 35 U.S.C. 112:

> The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention.

6. Claims 13, 16, 23-26, 33, 44-46, 48-53 rejected under 35 U.S.C. 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention.

7. Based on the new matter rejection, Examiner is unable to look to the specification for clarification of the term "directly". Applicant's arguments seem to suggest that directly blowing a gas onto a substrate requires a certain degree of

closeness or a perceptible amount of wind be felt, such as by sitting close to an air conditioner and feeling the cool air. Therefore, the term "directly" is a relative term, which renders the claim indefinite. The term is not defined by the claim, the specification does not provide a standard for ascertaining the requisite degree, and one of ordinary skill in the art would not be reasonably apprised of the scope of the invention.

Additionally, the phrase "the blowing does not affect the direction of the spray onto the device" is unclear. Any gas blown onto the device will inherently affect the direction of the spray to some degree. The specification states that the direction will only be affected if the gas is blown at higher speeds. Therefore, the claim can be interpreted to require a slower flow of gas. However, Examiner notes that if Applicant defines "directly" blowing to require enough force so that the gas flow can be felt, then the gas flow will be "felt" by the composition being sprayed, which invariably will alter the direction of the spray to some degree.

***Claim Rejections - 35 USC § 102***

8. Claims 1-6, 11, 13, 17-19, 21-24, 33-36, 44, 46, and 48-53 are rejected under 35 U.S.C. 102(e) as being anticipated by Castro et al. (US 6,395,326).

Examiner maintains the rejection of the previous office action for claims 1-7, 11, 13, 17-19, and 21-24.

As necessitated by amendment, claims 33-36, 44, 46, and 48-53 are added to this rejection for the reasons outlined in the previous office action and below.

Claim 7 has been withdrawn from this rejection.

It does not appear that Castro's blown gas affects the direction of spray from what is intended. Castro teaches rotation. The coating, gas, temperature and flow are inherently controlled by someone or by machine. Application is simultaneous with blowing the gas. Castro teaches the use of air, the use of atomized spraying, and a composition of polymer and paclitaxel. Gas appears to be blown directly.

***Claim Rejections - 35 USC § 103***

9. Claims 9-10, 15-16, 20, 25-26, 41, and 45 are rejected under 35 U.S.C. 103(a) as being unpatentable over Castro et al.

Examiner maintains the rejections of claims 9-10, 15-16, 20, and 25-26 for the reasons outlined in the previous office action.

Examiner adds claims 41 and 45 to this rejection, as necessitated by amendment. The rotation speed is a cause-effective variable and would have been obvious to optimize for the same reasons outlined in the previous office action regarding distance and flow rate. The use of inert gas is obvious for the reasons outlined in the previous office action.

10. Claims 1-6, 9-11, 13, 15-26, 33-36, 41, 44-46, 48-49, 51-53 are rejected under 35 U.S.C. 103(a) as being unpatentable over Ding et al. (US 6,358,556) in view of You et al. (US 6,407,009).

Examiner maintains the rejection of claims 1-6, 9-11, 13, and 15-26.

Examiner adds claims 33-36, 41, 44-46, 48-49, 51-53 to this rejection for reasons outlined in the previous office action and/or below.

It does not appear that Ding in view of You's blown gas affects the direction of spray from what is intended. Ding teaches rotation. The coating, gas, temperature and flow are inherently controlled by someone or by machine. Application is simultaneous with blowing the gas. Gas appears to be blown directly. The rotation speed is a cause-effective variable and would have been obvious to optimize for the same reasons outlined in the previous office action regarding distance and flow rate. The use of inert gas is obvious for the reasons outlined in the previous office action.

***Response to Arguments***

11. Applicant's arguments filed 3/30/2005 have been fully considered but they are not persuasive.

Applicant argues that Castro's heat conduit with nozzle and orifice used for directing heat onto the stent to dry its coating is not taught to direct heated gas onto the stent. Applicant speculates that a charged, glowing pin may be positioned in the orifice of the nozzle and used for the application of heat.

Examiner notes that conduits are used for conveying fluids, nozzles are used as projecting vents, and orifices are openings. Since Castro does not teach the conveyance and projection of a warm liquid (as such would wet, not dry the coating) , it is immediately clear to an ordinary artisan that Castro is conveying and projecting a gas. A heated pin would not require an elaborate conduit, nozzle or orifice to provide heat.

Heat supplied in the form of a gas, via a conduit, nozzle, and orifice (for example, like with a hair dryer) to dry a coated stent would have been immediately envisioned by one of ordinary skill in the art viewing this reference. A heated fluid that is not a liquid, must be a gas.

Additionally, even the heated pin envisioned by Applicant would heat the surrounding air which would be directed onto the stent to accomplish the task of heating the stent.

Applicant argues that Castro and Ding in view of You do not teach temperature adjustment based on vapor pressure of the solvent, wherein it is inhibited if the vapor pressure is above 17.54 Torr and induced if the vapor pressure is less than 17.54 Torr. Examiner disagrees and refers Applicant to the very explicit showing made my Examiner Jolley. The claim requires one of two scenarios based on vapor pressure. For example, Castro teaches the scenario in which the solvent has a vapor pressure lower than 17.54 Torr and uses a temperature to induce evaporation. The claim limitations have been met.

Applicant argues that You fails to teach "directly" blowing the gas and compares You to the indirect cooling felt in an air conditioned room.

Based on 112 rejections made above, Examiner does not feel Applicant has basis for such a claim limitation, nor for arguments made. The gas of You is intended to affect the substrate. It is directed onto the substrate. The specification does not provide requirements for the path the gas must take, the speed the gas must possess, or the

distance the dispenser must be from the substrate in order to meet the limitation of "directly:".

Applicant argues that You is not in the field of endeavor of Applicant (or, presumably, Ding) and argues that Examiner has broadened that field to any deposition of coating. Examiner disagrees.

Ding, You, and Applicant are all three concerned with spraying a solvenated polymer coating onto a rotating substrate, with the desire to control evaporation.

Applicant argues that You is not pertinent to the problem with which the invention was concerned and requires Examiner to explain why a person in the stent art would look to the semiconductor art. Additionally, Applicant argues there is no motivation to combine the Ding and You references.

Ding is concerned with forming a conformal, uniform coating by spraying on a rotating substrate and evaporating the solvent. You is concerned with forming a uniform coating by spraying on a rotating substrate and controlling the evaporation rate of the solvent. By controlling the evaporation rate, You can avoid non-uniform build-up of materials to provide a more even coating (col. 6, line 60-Col. 7, line 10). For these reasons and those provided by Examiner in the previous office action, the references may be combined. One practicing Ding would look to the prior art for accomplishing uniform coating when evaporating solvents. The teachings of You would provide a mechanism for controlling evaporation rates to achieve such uniformity. Just like the Ding and You

references, Applicant endeavors to solve a similar problem: preventing the liquid coating composition from collecting, clumping, or pooling (page 2 of the instant specification). Applicant and You are both concerned with preventing build-up of coating materials so as to produce uniform coatings on rotating substrates, sprayed with solvenated polymers.

In response to applicant's argument that the examiner's conclusion of obviousness is based upon improper hindsight reasoning, it must be recognized that any judgment on obviousness is in a sense necessarily a reconstruction based upon hindsight reasoning. But so long as it takes into account only knowledge which was within the level of ordinary skill at the time the claimed invention was made, and does not include knowledge gleaned only from the applicant's disclosure, such a reconstruction is proper. See *In re McLaughlin*, 443 F.2d 1392, 170 USPQ 209 (CCPA 1971).

***Conclusion***

12. Applicant's amendment necessitated the new ground(s) of rejection presented in this Office action. Accordingly, **THIS ACTION IS MADE FINAL**. See MPEP § 706.07(a). Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for reply to this final action is set to expire THREE MONTHS from the mailing date of this action. In the event a first reply is filed within TWO MONTHS of the mailing date of this final action and the advisory action is not mailed until after the end of the THREE-MONTH shortened statutory period, then the

shortened statutory period will expire on the date the advisory action is mailed, and any extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of the advisory action. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the date of this final action.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Jennifer K. Michener whose telephone number is (571) 272-1424. The examiner can normally be reached on Tuesdays.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Timothy H. Meeks can be reached on 571-272-1423. The fax phone number for the organization where this application or proceeding is assigned is 703-872-9306.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

Jennifer Michener
AU 1762
Primary Examiner
June 25, 2005

| FORM PTO-1449 (Modified) US Patent and Trademark Office | US DEPARTMENT OF COMMERCE | Docket No. 50623.149 | Application No. 10/040,538 |
|---|---|---|---|
| **INFORMATION DISCLOSURE CITATION in an Application** (Use several sheets if necessary) | | Applicant Pacetti et all. | |
| | | Filing Date December 28, 2001 | Group Art Unit 1762 |

## U.S. PATENT DOCUMENTS

| Examiner Initial | Ref. No. | Document Number | Date of Patent | Name | Class | Subclass | Filing Date if Appropriate |
|---|---|---|---|---|---|---|---|
| | A1 | 2,072,303 | 3/2/37 | Herrmann et al. | | | |
| | A2 | 3,882,816 | 5/13/75 | Rooz et al. | | | |
| | A3 | 4,269,713 | 5/26/81 | Yamashita et al. | | | |
| | A4 | 4,560,374 | 12/24/85 | Hammerslag | | | |
| | A5 | 4,839,055 | 6/13/89 | Ishizaki et al. | | | |
| | A6 | 4,865,879 | 9/12/89 | Finlay | | | |
| | A7 | 4,977,901 | 12/18/90 | Ofstead | | | |
| | A8 | 5,112,457 | 5/12/92 | Marchant | | | |
| | A9 | 5,328,471 | 7/12/94 | Slepian | | | |
| | A10 | 5,455,040 | 10/3/95 | Marchant | | | |
| | A11 | 5,464,650 | 11/7/95 | Berg et al. | | | |
| | A12 | 5,558,900 | 9/24/96 | Fan et al. | | | |
| | A13 | 5,578,073 | 11/26/96 | Haimovich et al. | | | |
| | A14 | 3,995,075 | 11/3076 | Cernauskas et al. | | | |
| | A15 | 5,605,696 | 2/25/97 | Eury et al. | | | |
| | A16 | 5,628,730 | 5/13/97 | Shapland et al. | | | |
| | A17 | 5,667,767 | 9/16/97 | Greff et al. | | | |
| | A18 | 5,670,558 | 9/23/97 | Onishi et al. | | | |
| | A19 | 5,700,286 | 12/23/97 | Tartaglia et al. | | | |
| | A20 | 5,716,981 | 2/10/98 | Hunter et al. | | | |
| | A21 | 5,800,392 | 9/1/98 | Racchini | | | |
| | A22 | 5,824,049 | 10/20/98 | Ragheb et al. | | | |
| | A23 | 5,830,178 | 11/3/98 | Jones et al. | | | |
| | A24 | 5,837,313 | 11/17/98 | Ding et al. | | | |
| | A25 | 5,851,508 | 12/22/98 | Greff et al. | | | |
| | A26 | 5,858,746 | 1/12/99 | Hubbell et al. | | | |
| ✓ | A27 | 5,865,814 | 2/2/99 | Tuch | | | |

APR 0 8 2005 PATENT & TRADEMARK

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | A28 | 5,873,904 | 2/23/99 | Ragheb et al. | | | |
| | A29 | 5,891,507 | 4/6/99 | Swaminathan | | | |
| | A30 | 5,971,954 | 10/26/99 | Conway et al. | | | |
| | A31 | 5,980,928 | 11/9/99 | Terry | | | |
| | A32 | 5,980,972 | 11/9/99 | Ding | | | |
| | A33 | 6,010,530 | 1/4/00 | Goicoechea | | | |
| | A34 | 6,015,541 | 1/18/00 | Greff et al. | | | |
| | A35 | 6,030,371 | 2/29/00 | Pursley | | | |
| | A36 | 6,042,875 | 3/28/00 | Ding et al. | | | |
| | A37 | 6,051,648 | 4/18/00 | Rhee et al. | | | |
| | A38 | 6,056,993 | 5/2/00 | Leidner et al. | | | |
| | A39 | 6,060,451 | 5/9/00 | DiMaio et al. | | | |
| | A40 | 6,080,488 | 6/27/00 | Hostettler et al. | | | |
| | A41 | 6,096,070 | 8/1/00 | Ragheb et al. | | | |
| | A42 | 6,099,562 | 8/8/00 | Ding et al. | | | |
| | A43 | 6,110,188 | 8/29/00 | Narciso, Jr. | | | |
| | A44 | 6,113,629 | 9/5/00 | Ken | | | |
| | A45 | 6,120,536 | 9/19/00 | Ding et al. | | | |
| | A46 | 6,120,904 | 9/19/00 | Hostettler et al. | | | |
| | A47 | 6,121,027 | 9/19/00 | Clapper et al. | | | |
| | A48 | 6,129,761 | 10/10/00 | Hubbell | | | |
| | A49 | 6,156,373 | 12/5/00 | Zhong et al. | | | |
| | A50 | 6,165,212 | 12/26/00 | Dereume et al. | | | |
| | A51 | 6,306,176 | 10/23/01 | Whitbourne | | | |
| | A52 | 6,358,567 | 3/19/02 | Pham et al. | | | |
| | A53 | 6,364,903 | 4/2/02 | Tseng et al. | | | |
| | A54 | 6,368,658 | 4/9/02 | Schwarz et al. | | | |
| | A55 | 6,503,954 | 1/7/03 | Bhat et al. | | | |
| | A56 | 6,534,112 | 3/18/03 | Bouchier et al. | | | |
| | A57 | 6,555,157 | 4/29/03 | Hossainy | | | |

## FOREIGN PATENT DOCUMENTS

| Examiner Initial | Ref. No. | Document Number | Date of Publication | Country | Class | Subclass | Translation Yes | Translation No |
|---|---|---|---|---|---|---|---|---|
| | B1 | EP 0 665 023 | 8/2/95 | EPO | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | B2 | EP 0 970 711 | 1/12/00 | EPO | | | |
| | B3 | WO 91/12846 | 9/5/91 | PCT | | | |
| | B4 | WO 97/45105 | 12/4/97 | PCT | | | |
| | B5 | WO 99/63981 | 12/16/99 | PCT | | | |
| | B6 | WO 00/02599 | 1/20/00 | PCT | | | |
| | B7 | WO 00/12147 | 3/9/00 | PCT | | | |
| | B8 | WO 00/64506 | 4/21/00 | PCT | | | |
| | B9 | WO 01/01890 | 6/6/00 | PCT | | | |
| | B10 | WO 01/45763 | 6/28/01 | PCT | | | |

**OTHER DOCUMENTS** (Including Author, Title, Date, Pertinent Pages etc.)

| | | |
|---|---|---|
| | C1 | Barath et al., *Low Dose of Antitumor Agents Prevents Smooth Muscle Cell Proliferation After Endothelial Injury;* JACC Vol. 13, No. 2; February 1989:252A (Abstract) |
| | C2 | Dichek et al., *Seeding of Intravascular Stents With Genetically Engineered Endothelial Cells,* Circulation 1989; 1347-1353. |
| | C3 | Forester et al., *A Paradigm for Restenosis Based on Cell Biology: Clues for the Development of New Preventive Therapies;* J. Am. Coll. Cardio. 1991; 17:758-769. |
| | C4 | Matsumaru et al.; *Embolic Materials for Endovascular Treatment of Cerebral Lesions;* J. Biomatter Sci. Polymer Edn., Vol. 8, No. 7 (1997) pp. 555-569. |
| | C5 | Miyasaki et al., *Antitumor Effect of Implanted Ethylene-Vinyl Alcohol Copolymer Matrices Containing Anticancer Agents on Ehrlich Ascites Carcinoma and P388 Leukemia in Mice;* Chem. Pharm. Bull. 33(6) (1985) pp. 2490-2498. |
| | C6 | Miyazawa et al., *Effects of Pemirolast and Tranilast on Intimal Thickening After Arterial Injury in the Rat;* J. Cardiovasc. Pharmacol. (1997) pp. 157-162. |
| | C7 | Ohsawa et al., *Preventive Effects of an Antiallergic Drug, Pemirolast Potassium, on Restenosis After Percutaneous Transluminal Coronary Angioplasty;* American Heart Journal (1998) pp. 1081-1087 |
| ✓ | C8 | Shigeno, *Prevention of Cerebrovascular Spasm by Bosentan, Novel Endothelin Receptor;* Chemical Abstract 125:212307 (1996). |

| EXAMINER | Michener | DATE CONSIDERED | 6/25/05 |
|---|---|---|---|

EVIDENCE APPENDIX "H"

# IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

| | | | |
|---|---|---|---|
| In re Application of: | | Examiner: | Michener, Jennifer Kolb |
| Pacetti et al. | | | |
| Serial No.: | 10/040,538 | Art Unit: | 1762 |
| Filed: | 12/28/01 | | |

Title: A System and Method for Coating Implantable Devices

---

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

## Declaration under 37 CFR § 1.132

I, Daniel Castro, declare the following:

1. I graduated from Massachusetts Institute of Technology in 1985 earning a BS degree in Chemical Engineering, with an emphasis on polymer science.

2. I have over 20 years of experience in the medical device and polymer fields, including experience in process and product development, coronary stent processing, polymer processing, coatings applications and drug eluting stent manufacturing operations.

3. I am currently employed by BioVascular Solutions, affiliated with Abbott Corporation, as a Manager, Process Manufacturing Engineering and Operations. (Prior to Abbott Corporation, BioVascular Solutions was an arm of Guidant Corporation.)

4. BioVascular Solutions is involved with the research, development and production of fully absorbable stents with a drug delivery coating.

5. I was employed by Guidant Corporation, a leading innovator of medical device products, as a Manager, Process Engineering Development from April 2001 to August 2004.

6. In my position as Manager, I have supervised engineers and group leaders in development and pilot programs; coordinated process transfers to larger scale production; specified requirements for clean room facilities; evaluated new process and material technologies for new products; and attended to process and product performance issues.

7. From January 2000 to April 2001 I was a Group Leader at Guidant Corporation.

8. In my position as Group Leader, I have supervised engineers and technicians in development of medical device programs; specified, evaluated, and procured equipment and fixturing for medical device programs; participated in strategic planning of product development projects; devised strategies for scale-up and transfer of new processes; evaluate new processes and material technologies for new products; and participated in troubleshooting process and product performance issues.

9. I was a Senior Manufacturing Engineer at Guidant Corporation from May 1998 to January 2000.

10. In my position as Senior Manufacturing Engineer, I proposed procedure and material modifications for process improvements; supported coronary stent manufacturing operations;

mapped process development strategy for future generation stents; initiated process development efforts for drug eluting stent program; and directed a cross-functional team to evaluate process and material alternatives.

11. I was employed as a Project Manager by Boston Scientific Corporation's Vascular Division from January 1994 to May 1998.

12. I was employed as a Process Engineer by Meadox Medicals from January 1991 to December 1993.

13. In my position as Process Engineer at Meadox Medicals, I developed and optimized processes for manufacture of zero preclot arterial prostheses; designed setups for medical device scale simulation of production operations; developed laboratory scale procedures into production scale processes; proposed and implemented changes of production procedures and characterization methods to improve medical device product quality; designed apparatus for manufacture of new products; and planned and performed process and product validations.

14. I was employed by Kingston Technologies as a Project Engineer from September 1988 to December 1990.

15. In my position as Project Engineer at Kingston Technologies, I extruded a novel hydrogel for biomedical tubing and coating applications; developed concepts, manufacturing and testing methods of new biomedical products; characterized plasticized extrudable hydrogel using NMR and melt rheology; directed the production and quality control of extrudable hydrogel;

standardized medical tubing production from compounding through finishing; and improved extrusion yields from 20% to >80%.

16. I was employed by Energia Inc. as a Research Engineer from November 1987 to September 1988.

17. In my position as a Research Engineer, I designed prototype and experimental apparatus for research and performed photochemical studies using lasers and lamps.

18. I am the first named inventor of U.S. Patent No. 6,395,326 assigned to Advanced Cardiovascular Systems Inc., which was a subsidiary of Guidant Corporation.

19. U.S. Patent No. 6,395,326 is now owned by Abbott Corporation.

20. I have read and understand the content of U.S. Patent No. 6,395,326.

21. I have read and understand the contents of Application Serial No. 10/040,538 assigned to Advanced Cardiovascular Systems Inc., now owed by Abbott Corporation.

22. I submit that U.S. Patent No. 6,395,326 does not teach "directing a gas, from a gas dispenser positioned at a distance from the coating dispenser, onto the implantable medical device, wherein if the solvent has a vapor pressure greater than 17.54 Torr at ambient temperature the temperature of the gas is adjusted to decrease the evaporation rate of the solvent, and if the solvent has a vapor pressure of less than 17.54 Torr at ambient temperature the temperature of

the gas is adjusted to increase the evaporation rate of the solvent," as recited by claim 1 of Application Serial No. 10/040,538.

23. I submit that U.S. Patent No. 6,395,326 does not teach "blowing a gas, from a gas blower positioned at a distance from the coating dispenser, directly onto the implantable medical device to either increase or decrease the evaporation rate of the solvent from the composition on the implantable medical device, wherein if the solvent is non-volatile the temperature of the gas is adjusted to increase the evaporation rate of the solvent, and if the solvent is volatile the temperature of the gas is adjusted to decrease the evaporation rate of the solvent," as recited by claim 23 of Application Serial No. 10/040,538.

24. I submit that U.S. Patent No. 6,395,326 does not teach "blowing a gas from a blower onto the stent to either increase or decrease the evaporation rate of the solvent from the coating substance on the stent based on the volatile properties of the solvent; and rotating the stent supported by the support assembly about a longitudinal axis of the stent," as recited by claim 54 Application Serial No. 10/040,538.

25. I believe that U.S. Patent No. 6,395,326 fails to teach what is recited in the independent claims of the above-identified application.

26. I further declare that all statements made herein of our own knowledge are true and that all statements made upon information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States

Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Executed on 10/13/06

Dan Castro

# EVIDENCE APPENDIX "I"

50623.149

# IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

| | | | |
|---|---|---|---|
| In re Application of: | | Examiner: | Michener, Jennifer Kolb |
| Pacetti et al. | | | |
| Serial No.: | 10/040,538 | Art Unit: | 1762 |
| Filed: | 12/28/01 | | |

Title: A System and Method for Coating Implantable Devices

---

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

## Declaration under 37 CFR § 1.132

I, Syed Hossainy, declare the following:

1. I earned a BS degree in Chemical Engineering from Bangladesh University of Engineering and Technology in 1988 and a PhD from University of Texas in 1992 for

2. I am currently employed by Abbott Corporation as a Director of Research and Development.

3. I am currently a Research Affiliate with Harvard-MIT Biomedical Engineering Center and am in collaboration with Dr. Elazer Edelman's lab in the area of cardiovascular implant and local pharmacokinetics.

4. I was a Fellow Director of Research and Development at Guidant Corporation from 2003 to 2006.

5. As a Fellow Director at Guidant Corporation my responsibilities included development of biomaterial strategy for controlled drug release technology; development of strategy for new medical device technology platforms; and development of controlled release technology for combination drug-device application, specifically drug eluting stents.

6. I was an Advisor at Guidant Corporation, Vascular Intervention Group from 2000 to 2003.

7. As an Advisor at Guidant Corporation my responsibilities included development of controlled release technology for local therapeutic effects, including for drug delivery stents; and selection of implantable biomaterials for drug delivery stent coatings and other cardiovascular devices.

8. I was a Principal Scientist and Project Leader at Guidant Corporation, Vascular Intervention Group from 1999 to 2000.

9. As a Principle Scientist and Project Leader my responsibilities included development of drug delivery stent technology.

10. I was a Senior Scientist and Project Group Leader at Johnson and Johnson Corporation (J&J) from 1996 to 1999.

11. At J&J, my responsibilities included development of anti-restenosis coronary stents; design of nonthrombogenic biomaterial surfaces; design of small diameter vascular graft surface; application of photocurable absorbable polymer in drug-delivery; enhancement of filler-matrix interfacial strength in composite biomaterial; processing of different I.V. absorbable polymers by

solution spinning; processing of different polymers by electrostatic spinning; and synthesizing and characterizing of novel antithrombogenic absorbable polymer.

12. I was a Senior Scientist at J&J Medical Inc. from 1995 to1996.

13. At J&J Medical Inc. my responsibilities included preparation of antimicrobial drug delivery indwelling catheters and development of surface modification for antithrombogenicity and anticalcification.

14. I am an inventor of U.S. Patent No. 6,395,326 assigned to Advanced Cardiovascular Systems Inc., which was a subsidiary of Guidant Corporation.

15. U.S. Patent No. 6,395,326 is now owned by Abbott Corporation.

16. I have read and understand the content of U.S. Patent No. 6,395,326.

17. I have read and understand the contents of Application Serial No. 10/040,538 assigned to Advanced Cardiovascular Systems Inc., now owed by Abbott Corporation.

18. I submit that U.S. Patent No. 6,395,326 does not teach "directing a gas, from a gas dispenser positioned at a distance from the coating dispenser, onto the implantable medical device, wherein if the solvent has a vapor pressure greater than 17.54 Torr at ambient temperature the temperature of the gas is adjusted to decrease the evaporation rate of the solvent, and if the solvent has a vapor pressure of less than 17.54 Torr at ambient temperature the temperature of

the gas is adjusted to increase the evaporation rate of the solvent," as recited by claim 1 of Application Serial No. 10/040,538.

19. I submit that U.S. Patent No. 6,395,326 does not teach "blowing a gas, from a gas blower positioned at a distance from the coating dispenser, directly onto the implantable medical device to either increase or decrease the evaporation rate of the solvent from the composition on the implantable medical device, wherein if the solvent is non-volatile the temperature of the gas is adjusted to increase the evaporation rate of the solvent, and if the solvent is volatile the temperature of the gas is adjusted to decrease the evaporation rate of the solvent," as recited by claim 23 of Application Serial No. 10/040,538.

20. I submit that U.S. Patent No. 6,395,326 does not teach "blowing a gas from a blower onto the stent to either increase or decrease the evaporation rate of the solvent from the coating substance on the stent based on the volatile properties of the solvent; and rotating the stent supported by the support assembly about a longitudinal axis of the stent," as recited by claim 54 Application Serial No. 10/040,538.

21. I believe that U.S. Patent No. 6,395,326 fails to teach what is recited in the independent claims of the above-identified application.

22. I further declare that all statements made herein of our own knowledge are true and that all statements made upon information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States

50623.149

Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Executed on 10/13/06

Syed Hossainy

EVIDENCE APPENDIX "J"

# IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

| | | | |
|---|---|---|---|
| In re Application of: | | Examiner: | Michener, Jennifer Kolb |
| Pacetti et al. | | | |
| Serial No.: | 10/040,538 | Art Unit: | 1762 |
| Filed: | 12/28/01 | | |

Title: A System and Method for Coating Implantable Devices

---

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

## Declaration under 37 CFR § 1.132

I, Li Chen, declare the following:

1. I earned a BS degree in Precision Instruments from Tsinghua University; a MS in Electrical & Systems Engineering from University of Connecticut; and PhD in Optical Engineering from Tsinghua University.

2. My employment includes Sr. Optical Engineer and Project Manager at Capella Photonics; Staff Engineer & Group Manager at Oplink Communications; and Principal Engineer, at Guidant Corporation.

3. At Guidant Corporation my responsibilities included laser welding attachment of radiopique markers to stents; laser bonding of polymer balloon; laser cutting for special metal stents; laser etching drug delivery stent; micro machining of micron size holes (5 microns) for porous drug delivery balloon and perforated tube for radiation system; operated sophisticated mechanical

tooling and fixture design such as an automatic loading/unloading system and a dual-beam switching system; and created medical devices innovations as well as medical device (stent) design using AutoCAD, SolidWorks, SmartCAM and FEA tools.

4. I am an inventor of U.S. Patent No. 6,395,326 assigned to Advanced Cardiovascular Systems Inc., which was a subsidiary of Guidant Corporation.

5. U.S. Patent No. 6,395,326 is now owned by Abbott Corporation.

6. I have read and understand the content of U.S. Patent No. 6,395,326.

7. I have read and understand the contents of Application Serial No. 10/040,538 assigned to Advanced Cardiovascular Systems Inc., now owed by Abbott Corporation.

8. I submit that U.S. Patent No. 6,395,326 does not teach "directing a gas, from a gas dispenser positioned at a distance from the coating dispenser, onto the implantable medical device, wherein if the solvent has a vapor pressure greater than 17.54 Torr at ambient temperature the temperature of the gas is adjusted to decrease the evaporation rate of the solvent, and if the solvent has a vapor pressure of less than 17.54 Torr at ambient temperature the temperature of the gas is adjusted to increase the evaporation rate of the solvent," as recited by claim 1 of Application Serial No. 10/040,538.

9. I submit that U.S. Patent No. 6,395,326 does not teach "blowing a gas, from a gas blower positioned at a distance from the coating dispenser, directly onto the implantable medical device to either increase or decrease the evaporation rate of the solvent from the composition on the

implantable medical device, wherein if the solvent is non-volatile the temperature of the gas is adjusted to increase the evaporation rate of the solvent, and if the solvent is volatile the temperature of the gas is adjusted to decrease the evaporation rate of the solvent," as recited by claim 23 of Application Serial No. 10/040,538.

10. I submit that U.S. Patent No. 6,395,326 does not teach "blowing a gas from a blower onto the stent to either increase or decrease the evaporation rate of the solvent from the coating substance on the stent based on the volatile properties of the solvent; and rotating the stent supported by the support assembly about a longitudinal axis of the stent," as recited by claim 54 Application Serial No. 10/040,538.

11. I believe that U.S. Patent No. 6,395,326 fails to teach what is recited in the independent claims of the above-identified application.

12. I further declare that all statements made herein of our own knowledge are true and that all statements made upon information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Executed on 10-13-2006 Li Chen

Li Chen

## RELATED PROCEEDINGS APPENDIX

There are no related proceedings.